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BLASTING QUARRY OPERATIONS: ADVERSE AND CUMULATIVE EFFECTS, LAWSUITS AND COMPLAINTS, AND SUGGESTED REMEDIES

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ABSTRACT

Breaking rock for road construction, installation of infrastructure or for extraction typically involves detonation of explosives. Any time explosives are detonated there are undesirable impacts on the environment and its inhabitants, which are always more severe in populated areas of significant human and non-human activity. The primary focus of this paper is on the impact that blasting quarry operations have on the environment and its inhabitants. A number of civil cases, investigations, published articles and press releases documenting the adverse and cumulative effects of blasting rock are presented, discussed and analyzed. The extensive number of documented cases and media reports of the adverse and cumulative effects of blasting quarry operations on the environment and its inhabitants shed light on the gas lighting strategy employed by the aggregate industry and their explosives engineers to alter the public's perception of reality by consistently and repeatedly claiming that blasting within regulatory limits cannot cause structural damage and that the vibrations felt from blasting are no more than a minor inconvenience. Gas lighting is a form of psychological manipulation in which the abusers, in this case the aggregate industry and its explosives engineers, attempt to sow self-doubt and confusion in the minds of their victims, and to mislead approval authorities and cause them to question their own judgment and intuition from a practical non-theoretical perspective. The research conducted supports reducing Peak Particle Velocity (PPV) to a maximum of 2 mm per second measured along the entire perimeter of a blasting quarry operation, combined with a permanent onsite 500-metre setback and offsite minimum separation distance of 1,000 metres from incompatible land uses to minimize damage from structural response to ground vibrations and airblast (concussion), and to eliminate or reduce substantially lawsuits and complaints from residents exposed to the adverse impacts of blasting. None of the *adverse effects* prohibited under the *Ontario* Environmental Protection Act are permitted to impact public or private third-party properties beyond the boundary of an existing or proposed blasting or non-blasting quarry operation.

Keywords: Quarry; Blasting; Mining; Environmental impacts; Legislation

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Blasting Quarry Operations: Adverse and Cumulative Effects, Lawsuits and Complaints, and Suggested Remedies

1. INTRODUCTION

The aggregate operations of rock quarrying and stone crushing continue to grow in scale globally (Marzouk, 2018)[1] and a quarry can remain operational for a significant period of time, especially, in jurisdictions such as Ontario, Canada, where a licence issued by the Ministry of Natural Resources to an aggregate operator has no expiry date. In the U.S, growth in the mining sector has been accompanied by an increase in the demand for explosives from 153,000 tonnes in 1989-90 to 450,000 tonnes in 2010 (Mishra & Rout, 2011).[2] An aggregate extraction operation can remain operational for 100 years plus, adversely impacting the environment and the health, safety and welfare of its inhabitants (Maponga et al., 2001)[3] for five or more generations. Assuming an average of two blasts a week, 50 weeks a year for 100 years would expose the environment and its inhabitants to the cumulative adverse effects of 10,000 blasts over the life of a quarry. About 50 blastholes per blast results in 500,000 separate detonations over a period of 100 years.

Rock quarrying and stone crushing are now part of a global phenomenon that has been the cause of concern everywhere in the world, including the advanced countries (Lameed & Ayodele, 2010).[4] Quarrying negatively affects the environment in a variety of ways from exploration and blasting, transport and disposal of waste rocks. The major environmental effects are the destruction of vegetation, disruption of animal habitats, diversion and blockage of natural drainage systems, soil erosion and river siltation, noise,…vibration [, flyrock debris] and dust pollution (Maponga & Munyanduri, 2001).[5] According to the Nova Scotia Supreme Court's ruling in *Macdonald v. Construction LTEE et al.* (1972),[6]

> *"…[T[he use of explosives, on the balance of probabilities, does involve danger to another's property. I cannot see how anyone can possibly describe such an operation as not being, in the language of the cases on the subject, "extra hazardous" or "inherently dangerous."* (Citing J. P.

[1] Marzouk, S.H., 'Influences of limestone stone quarries on groundwater quality' 2018 3 (4) International Journal of Human Capital in Urban Management 315-324. <https://www.ijhcum.net/article_34117_cb311e43b286d3457041ebfec70faa52.pdf> accessed 13 January 2023.

[2] Mishra, A.K. and Rout, M., "Flyrocks – Detection and Mitigation at Construction Site in Blasting Operation" (2011) 1(1) World Environment 1-5. <https://doi.org/10.5923/j.env.20110101.01>

[3] Lameed, G.A. and Ayodele, A., "Quarrying activity on biodiversity: Case study of Ogbere site, Ogun State Nigeria," (2010) 4 (11) African Journal of Environmental Science and Technology 740-750, <https://www.researchgate.net/publication/268000866_Effect_of_quarrying_activity_on_biodiversity_Case_study_of_Ogbere_site_Ogun_State_Nigeria> accessed 10 April 2023.

[4] Maponga, O. and Munyanduri, N., "Sustainability of the dimension stone industry in Zimbabwe — challenges and opportunities," (2009) 25(3) Natural Resources Forum 203-213. <https://doi.org/10.1111/j.1477-8947.2001.tb00762.x>

[5] Marzouk, S.H. and Mohamed, Abuo El-Ela A., "Influences of limestone stone quarries on groundwater quality," (2018) 3(4) Int. J. Hum. Capital Urban Manage 315-324. <http://www.ijhcum.net/article_34117_cb311e43b286d3457041ebfec70faa52.pdf> accessed 10 April 2023.

[6] *Macdonald v. Desourdy Construction LTEE et al*., 1972 CanLII 1150 (NS SC), <https://canlii.ca/t/gwg69> accessed 10 April 2023.

Porter Co. Ltd. v. Bell, [1955] 1 D.L.R. 62, 35 M.P.R. 13, and Rylands v. Fletcher)

According to Gui et al. (2018),[7] rock blasting can induce many adverse effects on the surrounding environment, including structural damage, business disruption and emotional traumatization of humans and non-humans (pets, livestock and wildlife):

> "*Explosion induces ground and structure vibration [1, 2] and annoying noise. When the explosive is detonated, an extremely high pressure pulse from the chemical reaction induced energy is generated which is transmitted into rock mass adjacent to the blast hole, producing a dilatational wave that propagates away from the charge. Stress wave due to blasts may cause damage to the surrounding rock and, furthermore, when the wave reaches a free face*[8] *or open fissure (non-transmission), it will be reflected and converted into tensile wave, which may produce tensile cracking and spalling if the tensile strength of the rock is exceeded by the tensile wave [3, 4]. Also due to the fact that some rock blasting projects are close to the inhabitant area, the surrounding buildings may be damaged due to blasting induced ground vibration if large strength wave propagates in the soil foundation and shock wave propagating through the air [5]. Disruption of some business activities, possible structural damage and emotional-traumatized residents are the problems that need to be addressed.*"

Before a blasting quarry is established, it is of critical importance to define and assess how the blasting quarry operation might impact neighbours, animals, structures, utilities and the environment in general (Bhandari & Jain, undated)[9] during the anticipated life of the quarry operation, a procedure that is consistent with the precautionary principle. Charles et al. (2019)[10] describes quarrying as follows:

> "*Quarrying can be defined as the blasting, breaking, crushing, cutting, grading, and washing of rocks for desirable economic purposes (Nwachulwu, 2000).*[11] *Quarry is a type of open-pit mining from which rock or minerals are extracted, quarries are generally used for the*

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7 Gui, Y.L., Zhao, Z.Y., Jayasinghe, L.B., Zhou, H.Y. Goh, A.T.C. and Tao, M., "Blast wave induced spatial variation of ground vibration considering field geological conditions," (2018) 101 International Journal of Rock Mechanics and Mining Sciences 63-68. <https://doi.org/10.1016/j.ijrmms.2017.11.016>.

8 *Face* is defined as "the end of an excavation toward which work is progressing or that which was last done. It is any rock surface exposed to air." The Blasting Primer, Second Edition, 2002.

9 Bhandari, S., and Jain, S., "Managing Social and Environmental Issues Due to Blasting Quarries," (2016) Earth Resource Technology, Jodhpure, India. <https://www.mineexcellence.com/download.php?filename=%27YWRtaW4vYXJ0aWNsZXMvTWFuYWdpbmcgQmxhc3RpbmcgYW5kIFNvY2lvbG9naWNhbCBJbXBhY3QgIC5kb2M=%27> accessed 23 February 2023.

10 Charles, E.H., Maxwell, E.N., and Stanley, I.E., "Health Impact Assessment of Commercial Rock Blasting: A Study of the Julius Berger Quarry in Mpape (An Area Highly Concentrated With Quarry Sites) in Abuja", (2019) 4 (8) International Journal of Engineering Applied Sciences and Technology 334-349 <https://www.ijeast.com/papers/334-349,Tesma408,IJEAST.pdf> accessed 23 February 2023.

11 Nwachukwu, A.E., "Industrial and Occupational Health and Safety," (2000) Owerri: Totan Publishers Limited.

production of building stones, dimension stones, construction aggregates, ripraps, sandstone and gravels (Rieke & Goldberg, 1972)."[12]

2. ADVERSE EFFECTS OF AGGREGATE EXTRACTION FAR REACHING

The *adverse effects* of aggregate extraction are far reaching, some permanent and irreversible and potentially deadly, more so with a blasting quarry operation where detonation of explosives result in *airblast, ground vibrations, toxic fumes* and *flyrock* (Sevelka, 2022;[13] Eltschlager, 2001),[14] all of which are known to negatively impact the environment and the health, safety and welfare of its inhabitants. The daily lives of those people who live, work and play in the communities in proximity to a blasting quarry operation are disrupted, with many living in a constant state of anxiety and fear of being injured or, worse yet, permanently disabled or killed. Numerous complaints and lawsuits (Lwin & Aung, 2019)[15] brought against the aggregate industry speak to the need for more stringent regulatory controls over aggregate extraction, especially in vulnerable populated areas of human and non-human activity. *Noise*, *vibration*, and *toxic fumes*, along with *flyrock*, are *contaminants* under the Ontario Environmental Protection Act (EPA), and have the potential to

- temporarily or permanently impact the environment
- compromise the health or safety of human and non-human life[16]
- negatively impact the quality of human and non-human life
- damage personal and real property
- damage public roads
- damage or preclude crop production (e.g., organic, specialty farming, etc.)
- disrupt business operations, including home occupations, and recreational activities (indoor and outdoor)
- cause subsidence (gradual caving or sinking of ground)[17]

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[12] Rieke, F.E. and Goldberg, O.P., "Industrial Clinic Services to Small Industries," (1972) 62 (1) American Journal of Public Health 69-72. <https://doi.org/10.2105/ajph.62.1.69>

[13] Sevelka, T., "Blasting Quarry Operations: Land Use Compatibility Issues and Property Value Impacts," (2022) 02 (03) Journal of Environmental Law & Policy 1-78. <https://doi.org/10.33002/jelp02.03.01>

[14] Eltschlager, K.K., "Regulatory Review of Blasting Related Citizen Complaints," (2001) <https://files.dep.state.pa.us/Mining/BureauOfMiningPrograms/BMPPortalFiles/Blasting_Research_Papers/OSM%20Reports/ISEE%202001-complaints.pdf> accessed 23 February 2023.

[15] Lwin, M.M. and Aung, Z.M., "Prediction and Controlling of Flyrock due to Blasting for Kyaukpahto Gold Mine," (2019) 5 (10) International Journal of Scientific Research and Engineering 338-346. <https://doi.org/10.31695/IJASRE.2019.33574>.

[16] In connection with the "Amaruq – Quarry amendment" project, the Environmental Assessment and Regulation Department of Economic Development and Transportation, Nunavut, in February 2017 expressed concerns about the impact blasting would have on wildlife: "Blasting activities associated with the operation of quarries have the potential to disturb and displace wildlife dependent on factors such as frequency of blasting, size of charges and the distance between the blast site and wildlife. Blasting can also cause injuries or death to wildlife from flying rocks."

[17] In *Jeans v. Carl B. Potter Limited and Lester Archibald Drilling & Blasting Ltd.* 1976 CanLII 2506 (NS SC), vibrations from blasting damaged two houses. According to the engineer testifying on behalf of the homeowners, blasting for road construction produced vibrations in the

- cause nuisance or trespass

According to a 2012 presentation by Morin of Explotech in the City of Ottawa, Ontario,[18] *"The derivatives of blasting which cause the greatest amount of concern to property owners adjacent to blast sites are flyrock, ground vibrations and overpressure (air blast). [Slide 90]"* Airblast, Ground Vibrations and Flyrock are described as follows:

- *"Air Overpressure or Airblast is a shock wave traveling through the air as a result of explosives detonation. It may be caused by rapid movement of burden or the release of expanding gas into the atmosphere (Figure 5.6). Audible airblast is called noise. Airblast at frequences below 20 Hz, inaudible to the human ear, is called concussion. Airblast annoyance and damage are related to the blast design, terrain, weather conditions and human response. It is measured with special gauges, pressure transducers or wide-response microphones. The seismograph shown in Figure 5.1 is equipped to monitor and record both ground vibrations (through the geophone) and airblast (through the microphone pick up). As with ground vibrations, both amplitude (in decibels) and frequency (in hertz) are measured [p. 62].[19] Air over Pressure (air blast) is often used to describe the air waves, which are generated by blasting activities. Air waves are compressed waves that travel through the air. Under certain weather conditions and poor blast design, air blast can travel considerable distances. Audible air blast is called noise, while air blasts at frequencies below 20 Hz and inaudible to the human ear are called concussions. Over pressure is usually expressed in pounds per square inch (PSI) or in decibels. (dB)*

soil. The vibrations compacted or densified the soils (a mixture of gravel, sand and silt) under the foundations of the two houses, causing movement in the buildings resting on the soil. One of the houses rested partly on bedrock, and as the soil settled on one end, the structure twisted. The movement of the two buildings in response to the vibrations caused cracking and twisting, resulting in twisted and jammed windows and doors, and cracked foundations. The explosions also caused changes in the subsoil water patterns, resulting in basement flooding. The two properties were also subjected to flying debris (flyrock) from blasting. Archibald, no longer a party to this action, acknowledged by its settlement a considerable responsibility for the damage to the two houses. [Jeans v. Carl B. Potter Limited and Lester Archibald Drilling & Blasting Ltd., 1976 CanLII 2506 (NS SC), <https://canlii.ca/t/jsk1g> accessed 30 January 2023].

[18] <https://www.slideserve.com/ami/city-of-ottawa-explosives-information-session-2012-exploedtech-engineering>

[19] Self-Study Guide for West Virginia Surface Mine Blasters Certification Examination, 3rd ed. revised 1998, Office of Explosives and Blasting, Virginia, USA.

(Bollinger, 1971;[20] Siskind et al., 1980;[21] Konya & Walter, 1985;[22] ABC, 1987,)[23] [p. 103]."

- *"Ground Vibrations is a technical term that is used to describe mostly man-made vibrations of the ground, in contrast to natural vibrations of the Earth studied under seismology. For example, vibrations caused by explosions, construction works, railway and road transport, etc. – all belong to ground vibrations.[24] Ground vibrations from blasting are acoustic waves that propagate through the Earth, termed "seismic" waves, because their propagation characteristics are similar to the vibrations produced by earthquakes (Crum et al., 1995).[25] Prediction of ground vibrations is difficult for the predetermined distances since the rocks, through which seismic waves propagate, are non-isotropic. Many factors affect the propagation of ground vibrations, making it almost impossible to include all the parameters (displacement, velocity, acceleration and frequency) with human disturbance and damage to structures (Erten et al., 2009).[26]" "Flyrock means any material propelled through the air from a blast[27]and can be gravel, rocks, tree trunks, construction materials, mud or even water.[28] Every blasthole has the potential to launch flyrock debris. Flyrock is rock that is propelled through the air or along the ground from a blast. It is extremely dangerous and is a potential cause of death, injury and property damage. Excessive flyrock may be caused by poor blast design, zones of weakness in the rock, or powder factors too high for the rock being*

[20] Bolinger, G.A., "Blast vibration analysis," South IL Univ. Press, Carbondale, IL (1971) p. 129. <https://scholar.google.com/scholar_lookup?title=Blast%20vibration%20analysis&publication_year=1971&author=G.A.%20Bollinger> accessed 10 April 2023.

[21] Siskind, D.E., Stachura, V.J., Stagg, M.S., and Kopp, J.W., "Structural response and damage produced by airblast from surface mining", US Bureau of Mine, RI 8485. <https://www.resolutionmineeis.us/sites/default/files/references/siskind-et-al-1980.pdf> accessed 10 April 2023.

[22] Konya, C.J. and Walter, E.J., "Rock Blasting," (1985) US Dept of Transportation, Federal Highway Administration, Virginia 199-257, <https://scholar.google.com/scholar_lookup?title=Rock%20blasting&publication_year=1985&author=C.J.%20Konya&author=E.J.%20Walter> accessed 10 April 2023.

[23] ABC, 'Atlas powder company, explosives and rock blasting. In: Field Technical Operations, Atlas Powder Co., Dallas, Texas, (1987) 321-411. <https://www.abebooks.com/book-search/kw/atlas-powder-company-explosives-and-rock-blasting/> accessed 30 January 2023.

[24] <https://en.wikipedia.org/wiki/Ground_vibrations>

[25] Crum, S.V., Siskind, D.E., Pierce, W.E., and Radcliffe, K.S., "Ground Vibrations and Airblasts Monitored in Swedesburg, Pennsylvania, from Blasting at the McCoy Quarry," U.S. Bureau of Mines, Minneapolis, March 19, 1995. <https://files.dep.state.pa.us/Mining/BureauOfMiningPrograms/BMPPortalFiles/Blasting_Research_Papers/State%20Reports/Ground%20Vibrations%20and%20Airblasts%20Monitored%20in%20Swedesburg%20PA%20from%20Blasting%20at%20the%20McCoy%20Quarry.pdf> accessed 10 April 2023.

[26] Erten, O., Konak, G., Kizil, M.S., Onur, A.H., and Karakus, D., "Analysis of quarry-blast-induced ground vibrations to mitigate their adverse effects on nearby structures," (2009) 1 (4) International Journal of Mining and Mineral Engineering 313-326. <https://www.academia.edu/25495122/Analysis_of_quarry_blast_induced_ground_vibrations_to_mitigate_their_adverse_effects_on_nearby_structures> accessed 10 April 2023.

[27] <https://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/301_319/307.pdf>.

[28] Workers Hazard Alert issued by the National Institute for Occupational Safety and Health (NIOSH), 2019, p. 3.

> *blasted. It is a leading cause of onsite fatalities and equipment damage from blasting. Flyrock has killed people over a mile [>1,609 metres] from the blast site. Flyrock has two sources, the open face of the bench and the surface of the bench. Even with good blast design and careful planning and loading, flyrock may occur. A blast area should be established which encompasses an area which would contain all flyrock. All persons not required by the blasting activities should be removed from the blasting area and the area should be guarded against unauthorized entry [p. 64].*" [29]

A *misfire*, a charge (explosive) or part of a charge, which, for any reason, has failed to detonate as planned, is also problematic and can result in the following adverse impacts (Taiwo et al., 2022):[30]

- Production of noxious (NO_x gas) fumes and toxic dust
- Inadequate ground movement
- Poor fragmentation
- Unusual blast sounds and ground vibration rate
- Generation of flyrock
- Evidence of undetonated explosive in bench face or muck pile.

While flyrock, an unavoidable by-product of blasting rock (Sevelka, 2022),[31] launched offsite and landing on private third-party property is a direct invasion and constitutes *trespass*, most jurisdictions also consider *airblast (concussion)* and *vibrations* emanating from the same blasting events as *trespass*, making no distfinction between a direct or indirect invasion of neighbouring properties. Courts have ruled that blasting is an extremely dangerous or ultra-hazardous activity, and those engaged in blasting that causes property damage, injury or death are held to strict liability or the rule of *Rylands v. Fletcher* (1866).[32]

In *John Rotert and Elizabeth Rotert v. Peabody Coal Company* (1974),[33] there were *physical* invasions of the Roterts' property by *vibrations* and *concussions*. The Roterts first noticed Peabody's blasting operation in 1968, at which time the Roterts spoke to Shorty Powell, the defendant's land man, about possible damage to their well. Subsequently, as the mining operation moved closer, the Roterts noticed cracks appearing in the living

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[29] Self-Study Guide for West Virginia Surface Mine Blasters Certification Examination, revised 1998, Office of Explosives and Blasting. <https://dep.wv.gov/dmr/blasting/Documents/Blasters%20Study%20Guide%20Chapters%201%20thru%208.pdf> accessed 10 April 2023.

[30] Taiwo, B.O., Abdulkadir, S.B., Moshen, J., Akinsode, K.A., and Oluwasanmi, E.A., "Blasting Misfire: A Review of Causes, Economic Effect, Control and Handling Techniques," (2022) 3 (1) International Journal of Research Publication and Reviews 967-972.

[31] Sevelka, T., "Blasting Quarry Operations: Land Use Compatibility Issues and Property Value Impacts," (2022) 02 (03) Journal of Environmental Law & Policy 1-78. <https://doi.org/10.33002/jelp02.03.01>

[32] The person who for his own purposes brings on his land and collects and keeps there anything likely to do mischief if it escapes, must keep it in at his peril, and, if he does not do so, is prima facie answerable for all the damage which is the natural consequence of its escape .... ." Fletcher v. Rylands, L.R. 1 Ex. 265, 279 (1866), and, Rylands v. Fletcher, L.R. 3 H.L. 330, 339-40 (1868).

[33] *John Rotert and Elizabeth Rotert v. Peabody Coal Company*, 513 S.W.2d 667 (1974). Mo. Court of Appeals. < https://casetext.com/case/rotert-v-peabody-coal-company > accessed 10 April 2023.

and dining rooms of their home, and Powell advised them not to do anything for three years. The mining operation continued toward the Roterts' home, and blasting was occurring any time of the day or night. Elizabeth Roterts started keeping a calendar log of some of the times the blasting was done, and of the severity of the explosions and there intensity, e.g., "hard", "very hard", "hardest yet" and "very, very hard." She wrote the notes:

> "*By months, the calendar describes these explosions, which when related to appellant's map showing dates and distances from appellant's property line…show this approximate information: July 1969, 4 explosions, when the strip was about 2,000 feet away; August 1969, 14 explosions, one hard, 1,850 feet away; September 1969, 6 explosions, 1,700 feet [610 metres] away; October 1969, 13 explosions, 3 very hard, 1,550 feet away; November 1969, 33 explosions, 1 hard, 6 "big shots", 1,450 feet away; December 1969, 34 explosions, 1,300 feet away; January 1970, 63 explosions, 10 hard, 2 very hard, 1,150 feet away; February 1970, 97 explosions, 15 hard, 20 very hard, 1,000 feet away; March 1970, 47 explosions, 15 hard, 13 very hard, 850 feet away; April 1970, 48 explosions, 16 hard, 9 very hard, 1 "hardest yet", 750 feet away; May 1970, 96 explosions, 2 hard, 47 very hard, 3 very, very hard, 600 feet away; June 1970, 87 explosions, 14 very hard; and on June 6, 1970, 3 very hard shots, and rocks fell from respondents' basement wall, 500 feet away; July 1970 (during which respondents were away for 9 days), 73 explosions, 23 hard, 10 very hard, 450 feet away; August 1970 (during which respondents were away 3 days), 37 explosions, 16 hard, 7 very hard, 350 feet away; September 1970, 85 explosions, 24 hard, 3 very hard, 300 feet away; October 1970, 66 explosions, 24 hard, 1 very hard —apparently about 1,000 feet to the northeast of appellant's property line in front of respondents' dwelling; on November 28, 1970, 3 days after suit was filed, there were 3 hard shots, about 250 feet from appellant's property line. Appellant stopped mining when it was 175 feet from its property line when ordinarily it would go to within 50 feet of the line. To the above distances, there should be added 125 to 175 feet [38.1 to 53.3 metres], as the evidence variously shows, from the property line to respondents' dwelling. By Elizabeth's log on the calendar there were more than 800 explosions from July 1969, through December 1970, after which she got to the place where she could no longer keep the log. Appellant's records show far more explosions than Elizabeth recorded, but undoubtedly, since its mining trenches were running in a north-south direction, many were a sufficient distance away from respondents' home not to be noticed.*"

The court noted the following:

> "*Elizabeth was awakened many times at night by the blasting, and the family was awakened and she would have trouble getting the children back to sleep. She lost so much sleep that she "simply couldn't function any more"; she could hardly live with the blasting and became crabby, nervous and jumpy as did John. She took medication, and developed a lot of epigastric distress and an ulcer for which she took Maalox and ate a bland diet. She was hospitalized two weeks. The medical testimony is*

> *omitted from the record at appellant's direction, and no issue is made as to the cause or extent of Elizabeth's physical condition, but it is conceded that she suffered no direct physical injury or contact from the blasting (other than from vibrations and concussions).In general, the evidence showed cracks in the plaster of the house, damage to the chimney, broken windows, damage to the basement walls and flue; cracking of a concrete floor of a pig farrowing barn, necessitating replacement, and from which little pigs developed E. Coli scours and died from a pathogenic strain of bacteria which built up in the cracks of the floor, and which could not be controlled by cleaning and disinfectant. There was also a kind of loosely packed, gritty dirt which blew over to respondents' house continuously when the wind was from the direction of the pits, which dirt stuck between the storm windows and the window and stayed there. In the fields there was a sulphur odour from the pits, and the water which built up in the pit was highly acidic. Elizabeth was in a constant state of worry lest her husband, who was blind, or her children would get into the pit.*"

Elizabeth Rotert made over 100 calls, including one to the president of the mine, but there really was no change in the blasting being done. The mine employees showed a great deal of indifference to the homeowner's complaints, and Powell would say, "Those shots aren't that hard," and would argue that it was the humidity, not the shot. Never did they give respondents an answer that indicated appellant was going to do anything about the blasting, which got worse and worse as appellant's blasting got closer to respondent's home. Other homeowners had also experienced the impacts from the blasting, and lodged numerous complaints with the mine company. One neighbour's livestock would sometimes get up and run after being frightened by a blast. The trial court ruled in favour of the Roterts on seven counts, five of which were upheld by the Missouri Court of Appeals, consisting of the following:

- Count I: Respondent's course of conduct in its strip-mining operations was willful, wanton and malicious in that it used high explosives indiscriminately and caused great noise, vibrations of earth, air concussion and shock waves, creating noxious fumes, odour, dust and smoke and damaged respondents' property and persons.
- Count III: for blasting damage occasioned by losses in respondent's pig farrowing business losing 400 pigs
- Count IV: Elizabeth Rotert was awarded $4,500 actual and $9,500 punitive damages for her emotional distress and illness.
- Count V: John Rotert was awarded $5,000 actual and $22,500 punitive damages for his loss of Elizabeth's consortium and for her medical expenses.
- Count VI: John Rotert was awarded $500 actual damages individually for nuisance because of fumes and dust, and the deep pit left by appellant across the road from respondents' home.

Count II, award for damage to buildings, and Count VII, Elizabeth and John, joint award for damages, were remanded for a new trial.

2.1 Airblast and Ground Vibration

A distant blast may produce noticeable airblast response even though the airblast amplitude could be relatively low. This airblast will be relatively low frequency, with little energy above 5 Hz, because the atmosphere selectively attenuates the higher frequencies. The occupants inside a house may not hear or notice the direct sound. However, if the house has a natural vibration frequency (structural response) near 5 Hz it will respond to the airblast and produce higher frequency secondary noise (rattling or shaking) (Crum et al., 1995)[34]

According to Ancich (1982),[35] where a residence is more than 500 metres from a quarry, air blast overpressure rather than ground vibrations is the source of residents' complaints, and that blasting overpressures are related to structural displacement and some aspects of housing design. Reportedly, spectral analysis (calculation of waves or oscillations) of airblast overpressure and sonic boom N-waves confirms the presence of significant energy at frequencies as low as 1Hz. Air-overpressure can cause structural damage and harm people (or non-human life) in the vicinity of quarry sites (Chen et al., 2022).[36]

Air-blast is that loud noise or "sonic boom" that is created by large blasts (with a frequency greater than 20 Hz) (Fretz, 2013).[37] At far receptor distances from a large blast, it is normally the air-blast, instead of ground vibration, that can be felt and can potentially cause anxiety, emotional distress and damage. The air-blast can cause a house to vibrate and could potentially shatter windows, and dislodge and damage fragile household contents (e.g., paintings, mirrors, crystal China). Air-blast generated from a blast can be disturbing to persons, pets, livestock and wildlife. The intensity of air-blast is affected by:

- the size and location of the blast;

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[34] Crum, S.V., Siskind, D.E., Pierce, W.E., and Radcliffe, K.S., "Ground Vibrations and Airblasts Monitored in Swedesburg, Pennsylvania, from Blasting at the McCoy Quarry," U.S. Bureau of Mines, Minneapolis, March 19, 1995. <https://files.dep.state.pa.us/Mining/BureauOfMiningPrograms/BMPPortalFiles/Blasting_Research_Papers/State%20Reports/Ground%20Vibrations%20and%20Airblasts%20Monitored%20in%20Swedesburg%20PA%20from%20Blasting%20at%20the%20McCoy%20Quarry.pdf> accessed 10 April 2023.

[35] Ancich, E., "The Environmental Aspects of Structural Response to Blasting Overpressure," 26th Annual Conference of the Institute of Quarrying, Australian Division, Hobart, Tasmania, Australia, November 1982, <https://www.researchgate.net/publication/259577550_The_Environmental_Aspects_of_Structural_Response_to_Blasting_Overpressure> accessed 10 April 2023.

[36] Chen, L., Asteris, P.G., Tsoukalas, M.Z., Armaghani, D.J., Ulrikh, D.V., and Yari, M., "Forecast of Airblast Vibrations Induces by Blasting Using Vector Regression Optimized by the Grasshopper Optimization (SVR-GO) Technique," (2022) 12 Applied Sciences 9805. <https://doi.org/10.3390/app12199805>

[37] Fretz, J., 'Comments on Exclusion or Inclusion of Air-Blast From Ajax EA Assessment, Technical Memorandum' May 21, 2013, Golder Associates. <https://www.kamloops.ca/sites/default/files/docs/our-community/13-05-21-golder-exclusioninclusionopinion-airblast.pdf> accessed 10 April 2023.

- the blast design, which includes number of blastholes, charge weight per delay and stemming depth;[38] [39]
- the blast shot direction;
- the terrain;
- wind direction and speed;
- cloud cover; and
- temperature inversions.

The effects of blasting on persons, property and wildlife, farm animals or pets are of concern to neighbouring residents. Residents who have experienced blasts may mistake the sudden noise and shaking of their house to be the result of ground vibration rather than air-blast, but nonetheless residents have a common concern for the effects of blasting on their persons and houses. Air blast is a matter of specific concern to sound-sensitive individuals, including persons suffering from Post-Traumatic Stress Disorder (PTSD), who may be adversely affected by air-blast events. Residents may also be concerned about effects on pets, farm animals or wildlife. Pets and farm animals with sensitive hearing, such as dogs and horses, may be disturbed by air-blast. Air-blast can frighten wildlife, particularly birds, and as such air-blast may have effects on nesting. The effects of blasting on property values are also of concern to residents. The nuisance, distress and/or damage from air-blast have an impact on desirability of affected neighbourhoods, with a corresponding impact on property values (Sevelka, 2022).[40]

2.2 Ontario Blast Design and the Use of Seismographs

Rock extraction typically involves the use of explosives, and requires preparation of a proponent-driven Blast Design Report (typically misleadingly labelled as a Blast Impact Assessment and devoid of meaningful analysis of potential *adverse effects*), which, theoretically, is only concerned with *noise (audible)* and *ground vibrations* under static environmental conditions and unknowable subsoil conditions, and does not reflect the dynamic and changing nature of aggregate operations over time. Often, the proponent-driven Blast Impact Assessment concludes with a speculative statement that there will be "no adverse effects" occasioned by the proposed blasting quarry operation. The standards for a Blast Design Report for a proposed blasting quarry operation in Ontario under the Aggregate Resources Act (ARA) are as follows:

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[38] Stemming is the inert material such as drill cuttings used in the collar portion or between explosives charges in a column (decks) of a blasthole so as to confine the gaseous products formed in an explosion. Also, the length of a blasthole left uncharged (Ludwiczak, 2002)."…Stemming significantly influences the control of flyrock, air-blast, and toxic fume generation (van der Walt and Spiteri, 2020; Oates and Spiteri, 2021)."

[39] "All fragmentation models predict the right tendencies when primary factors like specific charge and blast-hole pattern are altered. Quite often though the models make contradictory predictions e.g. about the influence of spacing to burden ratio and hole diameter etc. (Finn Ouchterlony, Swerec, Lulea University of Technology, 2003).

[40] Sevelka, T., "Blasting Quarry Operations: Land Use Compatibility Issues and Property Value Impacts," (2022) 02 (03) Journal of Environmental Law & Policy 1-78. <https://doi.org/10.33002/jelp02.03.01>

> Applications for a Class A licence or for an aggregate permit, for a quarry that would authorize the extraction or removal of more than 20,000 tonnes of aggregate per year must complete the following:
>
> "*A blast design report is required if a sensitive receptor [often code for human targets in occupied structures] is within 500 metres of the limit of excavation to demonstrate that provincial guidelines for blast overpressure and ground vibration can be satisfied.*"
>
> "*A Blast Design Report must be based on the Ministry of the Environment's Model Municipal Bylaw (NPC 119) with regard to guidelines for blasting relating to noise (concussion or overpressure) and ground vibration. The allowable limits as stated in NPC must be adhered to and if monitoring is not being routinely done then the cautionary limits will apply.*"
>
> "*Monitoring should normally be conducted at locations representative of the closest residence to the blast behind the face and/or closest residence to the blast in front of the face. The monitoring equipment locations should be between the blast and the residence and as close to the residences as possible.*"[41]

A government directive that instructs a quarry operator to install monitoring equipment (e.g., seismograph) on privately owned or tenant-occupied neighbouring residences without the consent of the homeowner or tenant is culpable for a civil action of trespass. It is equally unlawful to install monitoring equipment on public lands without authorization of the municipality or region.

The Ontario Aggregate Resources Act (ARA) Blast Design *standards*[42] are deficient as they fail to ensure that the 500 metres "from the extraction limit" be measured internally from the boundaries of the quarry site along the entire perimeter and contained entirely on the land owned by the proponent (i.e., quarry operator), which is inconsistent with the statutory obligation that *flyrock* not leave the site "if a sensitive receptor is located within 500 metres of the boundary of the site."[43] (Ontario Regulation 244/97)

The Blast Design standards also ignore existing or proposed short- and long-term land uses (e.g., zoning by-law, municipal or regional official plan) of the lands within a radius of 500 metres beyond the proposed quarry site. The standards also ignore entirely the rights of the owners of the lands within a radius of 500 metres to the lawful use and enjoyment of

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[41] Licence Applications: Noise Assessment and Blast Design Report Standards, Policy No: A.R.2.01.09, Date Issued: March 15, 2006, Ontario Ministry of Natural Resources. <https://files.ontario.ca/environment-and-energy/aggregates/269184.pdf> accessed 10 April 2023. A site plan for a quarry operation where there will be no blasting onsite, a condition must be added to the licence indicting that no blasting will occur during the life of the operation (see A.R. 2.00.03).

[42] Aggregate resources of Ontario standards: A compilation of the four standards adopted by Ontario Regulation 244/97 under the *Aggregate Resources Act*. <https://files.ontario.ca/mnrf-aggregates-combined-standards-en-2020-08-27.pdf> accessed 10 April 2023.

[43] *Site* is defined as "a piece of ground that is used for a particular purpose or where a particular thing happens, Collins Dictionary. <https://www.collinsdictionary.com/dictionary/english/site> accessed 22 January 2023.

their lands (vacant or improved) for the entire life of a quarry, which could remain operational for 100 years or more (five generations or more). A separation distance of 500 metres between a blasting quarry and incompatible land uses is also inadequate and should be increased to a minimum of 1,000 metres (Sevelka, 2022).[44] This deprivation of third-party property rights constitutes a de facto taking (i.e., expropriation) without compensation, for which the government or proponent should be held accountable.

An October 9, 2003 letter from the Director of the Northern Region of Ontario's Ministry of Environment (MOE) in reference to Land Use Guideline D-6 advises municipalities to determine the minimum separation distance and potential area of influence for a Class III industrial use (such as a quarry) in the vicinity of sensitive land uses (such as homes and farms). It establishes the following parameters[45]:

- 1,000 metres potential area of influence for any adverse effects "to be identified, mitigation proposed and an assessment made on the acceptability of the proposal" (MOE, D-6, Appendix C).

It is noteworthy that th[is] distance[] appl[ies] regardless of whether it is a new sensitive land use proposed in the vicinity of an existing Class III Industrial Use such as a quarry, or whether it is a new quarry proposed in the vicinity of existing sensitive land uses. As a matter of good planning, the primary consideration should be to minimize conflicts between incompatible land uses, regardless of which is exists and which is proposed.

In June 2018, the Town of Greater Napanee, Ontario, denied a lot severance application (PLCOR 2018 023) for land designated "Rural" in the Official Plan near a non-compatible blasting quarry operation, effectively depriving the homeowner from maximizing the use and value of his property. The denial of the homeowner's severance application results in an unwarranted financial benefit to the owner of the 40-hectare (98.842-acre) quarry (Thomas Contracting) who should be responsible for providing its own internal setback (even if it reduces the amount of aggregate that can be extracted) to protect the health, safety and welfare of third-party property owners, and who objected to the severance:

> *"I do not support this application as it does not meet the required MNR setbacks from an active quarry or pit operation. These regulations were put in place to prevent problems with home owners when blasting takes place and the daily operations of a licensed quarry/pit. Mr. Pietrangeli's existing house does not meet the required setbacks and he has frequently complained in the past whenever we blast (As recently as 2017). I am a little shocked he is applying for severance that would put a house closer*

[44] Sevelka, T., "Blasting Quarry Operations: Land Use Compatibility Issues and Property Value Impacts," (2022) 02 (03) Journal of Environmental Law & Policy 1-78. <https://doi.org/10.33002/jelp02.03.01>

[45] House Quarry Application, Township of Bays File: Z39/05 <https://static1.squarespace.com/static/5c59cf4c7a1fbd06dcdc52b6/t/5c6dff67f4e1fc98466d9c20/1550712680419/House+Quarry+Application+.pdf> accessed 10 April 2023.

> *to our quarry operation. In conclusion I am strongly against this severance being approved."*[46]

In *Martin Marietta Materials, Inc., et al. v. Board of Zoning Adjustment of Cass County*, (2007),[47] the Missouri Court of Appeals alluded to the Cass County Comprehensive Plan, which states that the use of land has adverse impacts, including reduction of property values and homeowner equity, beyond the boundary of the land being used (e.g., proposed blasting quarry operation), and the best way to avoid an externality is to separate incompatible land uses (e.g., residential use of neighbouring properties):

> *"One of the most basic factors affecting the use of a given parcel of land is the use of adjoining parcels. This is due to the fact that the use of land has an impact that goes beyond the boundary of the land being used. Economists refer to this impact as a `land use externality' because it is generally not included in the property owner's decision-making process since it is external to the efficiency and profitability of the property being used. As an example of land use externalities, a house surrounded by sand and gravel pits is less enjoyable to live in and has less value for residential purposes than the same house surrounded by similar houses. The noise, smoke and heavy truck traffic generated by the excavations are so incompatible with residential life that the value of the house declines. Yet the gravel pit owners [blasting quarry operations] have no economic incentive to lessen the impacts of their activities since the declining value of the house does not affect the profitability of their businesses. In effect, it is a cost imposed by the gravel pit [or quarry] owners on the owner of the house....The best way to minimize these external costs is to separate incompatible land uses or buffer them from each other [para. 15]".*

In *Wagner et al. v. Miami County Board of Zoning Appeal et al.* (2005),[48] the Ohio Court of Appeals upheld the trial court's judgment, which denied Wagner's rezoning application to permit a blasting limestone quarry operation on the following grounds, including the impacts of the proposed quarry operation on future neighbouring uses:

- The applicant failed to demonstrate that the proposed use will not change the essential character of the area.
- The applicant failed to demonstrate that the proposed use will not be hazardous or disturbing to existing and/or future neighbouring uses.
- The applicant did not comply with Section 21.11(C)(7) of the Miami County Zoning Code in that the proposed mineral, soil,

[46] <https://greaternapanee.civicweb.net/document/129127/Committee%20of%20Adjustment%20-%2025%20Sep%202018.pdf?handle=9BF5E6BF3E9F412282056785E1E76485> accessed 10 April 2023.

[47] *Martin Marietta Mater v. Bd of Zoning Adj.*, 246 S.w.3d 9 (2007) <https://law.justia.com/cases/missouri/court-of-appeals/2007/wd66637-2.html> accessed 10 April 2023.

[48] *Wagner et al. v. Miami County Board of Zoning Appeal et al.*, 2005-Ohio-1377, Ohio Court of Appeals, 2nd Appellate Dist. 2005. <https://www.supremecourt.ohio.gov/rod/docs/pdf/2/2005/2005-Ohio-1377.pdf> accessed 10 April 2023.

> and/or gravel extraction use will involve uses, activities, processes, material, equipment, and conditions of operation that are detrimental to any persons, property, or the general welfare by reason of excessive production of noise, smoke, fumes, etc.

These same concerns over the adverse effects of blasting quarry operations on neighbouring properties apply equally in the case of a rezoning request to expand an existing non-conforming quarry operation. For example, the purpose of Marin County's zoning ordinance is to "*discourage the expansion of non-conformities*, but to permit them to exist and to be maintained and enhanced to protect public safety and property values"[49]

In Ontario, Canada, a Blast Design report only addresses *noise* (the audible part of airblast above 20 Hz) and *ground vibration*, not the damage or harm that can be caused by blasting (detonating explosives), while ignoring other *adverse effects* associated with the detonation of explosives such as *flyrock* and *toxic fumes*, and the attendant diminution in property values. (A noise assessment report is only required if proposed excavation and/or processing facilities are within 500 metres of a sensitive receptor, [50] for a quarry operation, ignoring entirely land that is undeveloped or in agricultural or passive recreational use.) As reiterated below is pertinent:

> "*For every kilogram of ANFO [ammonium nitrate fuel-oil] that is detonated approximately 1,000 litres of gas are produced. These reaction gases principally consist of carbon dioxide (CO_2), nitrogen (N) and water vapour (H_2O). However, as such detonations do not occur under ideal conditions, other toxic gases may also be formed, such as carbon monoxide (CO), nitrogen dioxide (NO_2).*" (Rob Farnfield, publication AggNet)[51]

In surface blasting, much of the detonation presents itself as a cloud of gas and dust coming off the blast. In addition, the gases generated from detonation of the explosives may be present in the muck pile[52] and may also move into cracks and fissures in the ground. The gases move through the ground and may collect in nearby confined spaces such as underground sewers, pipeline trenches, or basements of nearby homes and businesses. In most cases the fumes will spread slowly through the ground

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[49] *Point San Pedro Road Coalition v. County of Marin et al.*, 33 Cal.App.5th 1074 (2019) 245 Cal.Rptr.3d 580. <https://casetext.com/case/point-san-pedro-rd-coalition-v-cnty-of-marin-1> accessed 10 April 2023.

[50] "Summer time noises have the greatest potential for causing annoyance because of open windows, outside activities, etc. During the winter people tend to spend more time indoors and have the windows closed. In general, building walls and windows that are closed provide a 15 dB reduction in noise levels. Building walls with the windows open allow for only a 5 dB reduction in SPL [Sound Pressure Level]. Assessing and Mitigating Noise Impacts, New York Environmental Conservation Law Articles, Jeffrey Sama, February 2, 2001. <http://www.airandnoise.com/NYDEP-00-1.pdf> accessed 10 April 2023.

[51] Farnfield, R., "Blast Fumes From ANFO Mixtures," *AggNet*, undated. <https://www.agg-net.com/resources/articles/drilling-blasting/after-blast-fumes-from-anfo-mixtures> accessed 21 January 2023.

[52] *Muck Pile* is defined as "the pile of blasted and broken rock or dirt after the shot [blast] has been detonated, that has to be loaded and removed." The Blasting Primer, Second Edition, A Study Guide for Blasters and Students of Explosives Engineers, Progress Printing Company.

in all directions, and, in some cases, a preferential pathway may exist which allows the gases to move in one direction (Mainiero et al., 2007).[53]

A review of US accident statistics undertaken by Santis (2003)[54] since 1992 related to incidents involving the use of explosives detailed 11 occasions where after-blast fumes had seriously affected the public, three occasions where a worker had been affected, and one work-place fatality. Toxic fumes, fugitive dust, sound (noise) and vibrations, along with flyrock, are *contaminants* under the Ontario Environmental Protection Act (EPA) (RSO 1990. c E.19, s 1(1), defined as follows:

> "*contaminant*" *means any solid, liquid, gas, odour, heat, sound, vibration, radiation or combination of any of them resulting directly or indirectly from human activities that causes or may cause an adverse effect.*
>
> And, "*adverse effect*' under the *Ontario* EPA, means one or more of,
>
> (a) impairment of the quality of the natural environment for any use that can be made of it,
> (b) injury or damage to property or to plant or animal life,[55]
> (c) harm or material discomfort to any person,
> (d) an adverse effect on the health of any person,
> (e) impairment of the safety of any person,[56]
> (f) rendering any property or plant or animal life unfit for human use,
> (g) loss of enjoyment of normal use of property, and

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[53] Mainiero, R.J., Harris, M.L. and Rowland III, J.H., "Dangers of Toxic Fumes from Blasting" (2007) <https://www.cdc.gov/niosh/mining/userfiles/works/pdfs/dotff.pdf> accessed 10 April 2023.

[54] Santis, L.D., "An analysis of recent accidents during the use of commercial explosives," (2003) International Society of Explosives Engineers, Nashville Conference. <https://www.agg-net.com/resources/articles/drilling-blasting/after-blast-fumes-from-anfo-mixtures> accessed 10 April 2023.

[55] In *Ontario (Natural Resources and Forestry v. South Bruce Peninsula (Town)*, 2022 ONCA 315, the Ontario Court of Appeal upheld the decisions of the lower courts, which ruled that the Town had "damaged" the habitat of a *species at risk*, pursuant to section 10(1) of the Endangered Species Act (ESA), which states, in part, "No person shall damage or destroy the habitat of (a) a species that is listed on the Species at Risk in Ontario List as an endangered or threatened species…." The Court of Appeal also referred to the goals set out in the preamble to the ESA, namely to prevent the "loss of species caused by human activities which damage the habitat of the species" and to "prevent damage to avoid or minimize threats to endangered species." The appeal court also reiterated the statement in the Supreme Court of Canada decision *Castonguay Blasting Ltd. v. Ontario (Environment)*, 2013 at para. 9 regarding the need to generously interpret the ESA in light of its remedial nature and its objective of environmental protection. "Damage," as defined by the trial judge, namely to cause something to be "less attractive, useful or valuable," was found to be appropriate and should be understood from the perspective of the species at risk. The Court of Appeal also noted that "the application of the *de minimus* [small or trivial] defence to charges under the ESA must be undertaken with caution "because of the potential cumulative effect of small damage over an extended period of time," as is typical of the damage caused by repeated detonation of explosives. As *minor damage* to the environment and its inhabitants can build over time and become irreversible, this finding by the Court of Appeal is equally applicable to the Environmental Protection Act (EPA).

[56] In *Ontario v. Canadian Pacific*, [1995] 2 SCR 1031, the Supreme Court of Canada, quoting favourably from *R. v. Stellato* (1993), 78 C.C.C. (3d) 380, aff'd, [1994] 2 S.C.R. 478, concluded that "[i]f the evidence of impairment establishes any degree of impairment ranging from slight to great, the offence has been made out."

(h) interference with the normal conduct of business; ("conséquence préjudiciable")

Adverse effect has the same meaning in the 2020 Ontario Provincial Policy Statement, p. 39. The adverse effects, individually or collectively, associated with a blasting (or non-blasting) quarry operation are inconsistent with planning, building and maintaining *healthy and sustainable communities*, and have the potential to reduce residential and non-residential property values, and, in turn, erode a municipality's tax base for the entire life of a quarry operation (C4SE, 2009[57]; Smith, 2014[58]).

An examination of 12 Blasting Impact Assessments (BIAs) prepared by explosives engineers on behalf of the aggregate industry were found to focus entirely on (undefined) "sensitive receptors" and to completely disregard addressing property damage, quality of life and the health and safety of human and animal life. Other shortfalls or omissions routinely identified in a Blasting Impact Assessment are listed as follows:

- Potential *Nuisances* occasioned by blasting operations not mentioned;[59]
- "Adverse effects" not defined, inadequately addressed or overlooked;
- *Flyrock* (the ultimate adverse effect) not defined, inadequately addressed or overlooked;
- Calculations of rock throw (distance) made without provision for a safety factor (e.g., for protection of onsite quarry employees, for weather conditions, for uncontrollable factors and for unforeseen factors such as human error);[60]
- Reciprocal setback measurements from lot limits of sensitive receptors (e.g. homes, farms, parks, heavily-travelled roads, school bus routes) closest to a proposed quarry not provided;
- Presence of nearby above-ground and below-ground utilities not identified or disclosed;
- Presence of school bus routes, biking routes, trailways, bridges, etc., not identified or disclosed;
- Character of the area not described or inadequately addressed (some land uses are more sensitive than others, but virtually none are compatible with a proposed blasting quarry and its adverse effects);
- Present and future population demographics (permanent, seasonal and transient) for an appropriately defined external

[57] The Potential Financial Impacts of the Proposed Rockfort Quarry, C4SE, February 26, 2009 <https://files.secure.website/wscfus/6880241/uploads/C4SE.pdf> accessed 21 January 2023.

[58] Smith, G., "Economic Costs and Benefits of the Proposed Austin Quarry in Madera County," October 23, 2014 <https://www.stop3009vulcanquarry.com/wp-content/uploads/2018/01/Austin-Quarry-Economics-Report.pdf> accessed 21 January 2023.

[59] Only one Blasting Impact Assessment examined mentioned "nuisances."

[60] There are numerous formulas for calculating rock "throw," but none are particularly accurate as they cannot capture the dynamic and unpredictable nature of detonating explosives in rock (Lwin and Aung, 2019).

zone of influence or planning district during the expected life of the quarry operation not provided;

- Description of "sensitive receptors" not provided;
- Activities associated with each "sensitive receptor" not disclosed;
- Size (scale), age, construction and condition of each "sensitive receptor (i.e., structure, bridge, monument, etc.)" not provided (every structure has a different level of tolerance to ground vibrations and airblast from repeated detonation of explosives);
- Number of occupants and pets (if applicable) and use of "sensitive receptor (e.g. residential, business, institutional or recreational) that will be adversely impacted by blasting not addressed;
- Expected life of proposed quarry operation (i.e., all phases) not disclosed; and
- Estimated frequency and number of blasts, including average number of detonations per blast, during the expected life of the quarry operation not disclosed.

The superficial nature of the Blast Impact Assessments examined precludes meaningful analysis of potential health and safety risks, quality of life issues and potential nuisances that residents (and passers-by, visitors, workers, business employees and patrons) can expect to experience as a result of quarry blasting operations during the anticipated life of the quarry. A Blast Impact Assessment that fails to include a meaningful analysis of *flyrock*, the ultimate adverse effect, is, at best, misleading, and, at worst, points to incompetence, negligence or depraved indifference. Just because the Ontario ARA does not specifically mandate an analysis of flyrock as part of a Blast Design, no responsible and ethical engineer preparing a proponent-driven BIA would ignore or dismiss the issue of flyrock (an unavoidable by-product of blasting rock), which is considered the ultimate adverse effect of blasting, and deemed an extremely dangerous or ultra-hazardous activity by the courts.

Suspicions and root causes behind *flyrock* and the under-reporting of *flyrock* incidents in Ontario were discussed by participants during an interactive forum at the 2011 annual general meeting of the Western Canada Chapter of the International Society of Explosives Engineers in Vernon, BC (Loeb, 2012):

> *"Flyrock incidents in Ontario are probably just not being recorded. The fine is for flyrock leaving a property onto another property. Often that is not seen and the evidence would be swept off the street. I would strongly suspect that several flyrock incidents in Ontario are not recorded…."* (A. Grogan, pers. comm., October 16th 2011).

A Blast Design, even with the limited criteria under the Ontario ARA, prepared by an explosives engineer for a proposed quarry operation is not a science: it is very much an after-the-fact trial and error process

(Pugliese, 1972)[61] left entirely to the discretion of the blaster-in-charge throughout the anticipated life of the quarry, which does not bode well for the environment and the health, safety and welfare of human and non-human life. In Ontario, Canada, a blaster does not require a license as proof of some measure of competency in blast design.

The earth consists of many particles of soil or rock which are cemented together. There is a small amount of elasticity in the cementing material and even in the rock as well, and vibration is actually the displacement or movement of these particles caused by the seismic wave as it passes through the earth. The displacement of these particles is only a small fraction of an inch. The elastic nature of the cement causes the particles to oscillate. As the seismic wave alternate completely, the particles come back to the original position. It is these oscillations of the individual particles that are measured to find the magnitude of blast vibration (Tariq, undated).[62]

Drilled blastholes filled with explosives are detonated behind the working face of the materials to be quarried to blast loose the rock mass for harvesting. When the explosives are detonated a detonation moves through the explosive at a speed of about 18,000 feet per second (5,486 metres per second) changing the solid material to a gas at a very high rate. This detonation wave and rapidly expanding gas will create a cavity, crushing, cracking and moving the surrounding material. It will generate two types of waves into the earth around the explosion. First a surface wave, or Ryleigh wave, that will damp out and disappear in a relatively short distance. Then a second wave will travel great distances in the bedrock (under any barrier). It is this second body wave that will move through the bedrock and cause the earth above the bedrock to vibrate and shake homes and other structures, even at large distances from the explosion site. There is no way to mitigate or block the movement of these body waves. Following statement is worth mentioning in the context:

> "*Onsite barriers and buffers will not shield neighbouring properties from the sound and vibration damages of blasting. The hemispherical shock wave emanating from an explosion is similar to a sound wave in that the wave expands in all directions and will simply move over any barrier as though it was not there.*" (Pers. Comm. of Dr. Kiger, explosives expert, proposed Granite Quarry in Alvaton, Meriwether County, GA, 2018)

[61] Pugliese, J.M., "Designing Blast Patterns Using Empirical Formulas, A Comparison of Calculated Patterns With Plans Used in Quarrying Limesotne and Dolomite, With Geologic Considerations," Twin Cities Mining Research Center, Minneapolis, Minn., 1972 <https://miningandblasting.files.wordpress.com/2009/09/designig_blast_patterns_using_emperical_formula.pdf> accessed 21 January 2023.

[62] Tariq, S.M., "A Comparative Study of Calculated and Measured Particle Velocities," Pakistan Engineering Congress, 69th Annual Session Proceedings, 2001. <https://pecongress.org.pk/images/upload/books/657.pdf> accessed 21 January 2023.

The stress wave from the detonation of the explosives causes radial fracturing of the rock mass at 1.5 to 8 feet per millisecond.[63] Blasting to fragment (break) and move rock unfortunately produces ground vibrations and airblast as wasted energy, which results in unintended consequences exposing the environment and human and non-human life to numerous *adverse effects* each time explosives are detonated, in addition to the potentially deadly consequences of flyrock. It is further explained as:

> "*Ground vibration, flyrock and noise consume about 80% of the total energy produced by explosives, and only 20% is used in rock fragmentation (Parida and Mishra, 2015[64]). See the YouTube video of a Blasting Crew Loading Explosives and Blowing Up Solid Rock.*"[65]

Blasting of rock causes irreversible transformations such as ruptures, cracks, fissures or subsidence in the area surrounding a quarry site after every blast (Garaliu-Busoi et al., 2021),[66] which are exacerbated by the cumulative effect of repeated blasting. Subsidence is defined as:

> "[A]ny movement of the soil from its natural position. This movement may be in any direction. It may be of surface or subsurface soil. A shifting, falling, slipping, seeping or oozing of the soil is a subsidence within the meaning of the term as used in this Chapter (*Restatement (Second) of Torts* § 817, comment *h* at 68 (1977)".[67]

Knowledge of the type and intensity of the rock defects is much more important than the rock type to be encountered in blasting. A discontinuity is defined as a significant mechanical fracture that has low shear strength, negligible tensile strength, and high fluid conductivity with the rest of the rock material. Rock mass is rarely continuous or isotropic and is composed of intact blocks of rock separated by discontinuities like faults, cleavages, fissures, fractures, joints, bedding planes, shear zones, etc. The behaviour of the rock mass is dependent on the nature and frequency of these discontinuities, the shape of the intact rock defined by the discontinuities and the properties of the intact rock. It is the discontinuities that control

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63 Blaster's Training Module 3 –Surface Blast Design. <https://www.osmre.gov/sites/default/files/inline-files/Module3_0.pdf> accessed 21 January 2023.

64 Parida, A., and Mishra, M.K., "Blast Vibration Analysis by Different Predictor Approaches-A Comparison," (2015) 11 Procedia Earth and Planetary Science 337-345. <https://www.sciencedirect.com/science/article/pii/S1878522015001216> accessed 21 January 2023.

65 <https://youtu.be/fg2hefTwZ00> accessed 21 January 2023.

66 Garaliu-Busoi, B., Kovacs, A., Gheorghiosu, E., Radeanu, C., and Miclea, O., "The importance of seismic protection of strategic objectives, in the area of influence of useful rock quarries, in which blasting in carried out," (2021) National Institute for Research and Development in Mine Safety and Protection to Explosion. <https://www.matec-conferences.org/articles/matecconf/pdf/2021/11/matecconf_simpro21_02002.pdf> accessed 21 January 2023.

67 In *Island Creek Coal C. v. Rodgers*, 644 S.W.2d 339 (1982), Ky Court of Appeals, an April 29, 1977 blast at the surface coal mine, consisting of 16 blastholes 32 feet deep, each containing 275 pounds of ANFO for a total of 4,400 pounds (1,996 kgs), caused subsidence which damaged homes in a subdivision located 13,200 feet (4.023 kilometres) at the closest point from the blast site.

the engineering performance of a rock mass, not the intact rock (Quarry Magazine, 2012).[68]

In the case of *Gateway Estates Park Condominium Association* (2018),[69] the condominium association manages a mobile home community of 220 homes and two vacant lots. The condominium association holds title to a number of common elements, including man-made South Lake which was excavated sometime before 1975 when the condominium was registered. In 2005, *SDI Quarry*, which operates the only mines at which blasting is conducted in close proximity to the community, began blasting at three mines near South Lake, no closer than 7,000 feet (2.13 kilometres) from the mobile home community, averaging about 20 blasts a year. Each blast was monitored and the vibrations recorded. All were within lawful levels established by state law (the limit is a peak particle velocity (PPV) of 0.5 inches per second or 12.7 mm/sec). None exceeded 0.2 ips (5.08 mm/sec) PPV at South Lake, with most being 0.1 ips (2.54 mm/sec) PPV. No damage to South Lake was evident for five to six years of blasting until 2011, when its shore first began to show signs of destabilization and the ground collapsing:

> "*In 2011, about five or six years after Appellee began its blasting activities, the shore of the South Lake began to destabilize, and saturated soil at the edge of the lake began to slough and slump into the water. This opened up fissures in the slope, which undermined the upward bank. In time, holes appeared in the bank, and pieces of the once level surface fell off, resulting in a narrowing of the horizontal area from roughly five feet to about a foot and a half. Residents observed the ground falling into the water in close temporal proximity to the blasting.*"

In late 2014 or early 2015, *Gateway Estates* retained James McNew, owner of Upper Keys Consulting, to give recommendations concerning restoration of the lake bank. Upper Keys Consulting prepared an estimate in the amount of $840,000 for restoring the shore of South Lake and installing preventive devices to protect the shoreline against erosion from further blasting. This led to litigation against *SDI Quarry* under Florida's Construction Materials Mining Activities Administrative Review Act. Blasting continued without interruption, and between July 1, 2015 and October 17, 2016, there were 25 blasts. Based on this figure, the administrative law judge inferred that the number of historical blasts that had impacted South Lake was 200 to 250. Whether the detonations caused harm to South Lake's shoreline was the focal point of the administrative proceedings, quoting:

> "*[That] the blasts were all within state standards…doesn't negate potential liability.*"

It was acknowledged that "no generally accepted scientific standard exists as to relevant threshold PPV levels for when man-made lakeshores would be adversely affected by vibrations from afar." McNew, over the

[68] Quarry Magazine, "Reducing piles through better blasting," (2012) PCM_ADMIN. <https://www.quarrymagazine.com/2012/07/08/reducing-piles-through-better-blasting/> accessed 21 January 2023.

[69] *SDI Quarry v. Gateway Estates Park Condominium Association*, 249 So.3d 1287 (2018)

objections of the *SDI Quarry*, was qualified to testify "as an expert on causation." McNew, holding a degree in mechanical engineering, had no training or significant education in seismology, geotechnical engineering, or geology. McNew testified that he consulted extensively with an engineer, and they produced a set of notes based on their extensive research of the literature, and these formed the basis of his opinion as the causes of the slope stability failures around South Lake.

> "*McNew opined that vibrations from Appellant's blasting caused the problems at Appellee's lake. Specifically, he explained that these vibrations acted upon the soft layer of silt atop the shore and bank of the South Lake, causing the liquefaction of this saturated soil extending up to eight feet beneath the surface. This led to the compaction of the loose, wet soil around the edges of the lake, opening up cracks and holes and weakening the slope, which began to erode and fail. McNew conceded that there were no legal standards in Florida or elsewhere establishing thresholds above which lakeshore slope instability would be expected under the stress of blast-related vibrations. In formulating his opinion, McNew stated that he used Transit Authority Guidelines rather than mining guidelines because the transit guidelines provided a more realistic standard where the damages were not to buildings. McNew also ruled out other possible causes such as earthquakes or heavy truck hauling near the lake.*"

Ruling in favour of *Gateway Estates*, the administrative law judge found McNew's opinion on causation more persuasive than the competing view offered by *SDI Quarry's* experts. In doing so, the judge noted that:

> "*Steven Black's categorical opinion that blasting could not be a cause of the damage to Appellee's lake was undercut by his concession that heavy truck traffic could affect the silt layer of a lakeshore over a continuous period of time. The administrative law judge also found that the circumstantial evidence supported McNew's opinion. Specifically, he noted that 'the South Lake had existed for at least 35 years without experiencing the deterioration of the shore and bank that became noticeable within just five or six years after the start of the blasting, and which worsened over time as the blasting has continued.' He also noted 'the persuasive evidence that visible damage occurs in the wake of individual blasts'.*"

Black's evidence was accepted by the administrative law judge to the extent that wind, wave and rainwater was a natural cause of some of the bank erosion at South Lake, and found that *SDI Quarry's* blasting combined with the natural forces constituted a legal cause of the claimed property damages. Adding, "*as a matter of fact,' the property damage at issue is present and continuing; the harm to the lakeshore is cumulative, indivisible, and inseparable.*"

Finding that blasting is an ultra-hazardous activity for which strict liability is imposed, the administrative law judge concluded that *Gateway Estates* was not required to prove *SDI Quarry* was negligent or that *SDI Quarry's* blasting was the sole cause of *Gateway Estates'* damage. *Gateway Estates* was awarded $840,000 in damages. In a continuing tort (trespass),

the statute of limitations runs from the time of the last tortious act.[70] The Florida appeals court, in a unanimous ruling, upheld the administrative order.

2.3 The Use of Seismographs and its Limitations in Measuring the Adverse Effects from Blasting Rock

A seismograph is an instrument that measures earth-borne vibrations at a specific location induced by an earthquake or blasting, and, at best, it can be used to determine movement of the ground surface. Sometimes the intensity of blasting reverberates to such an extent that it is heard and felt at a great distance from the blast site that the blast is mistaken for an earthquake. For example, a blast at a quarry in the Town of South Bruce Peninsula, Ontario, in 2019, was initially mistaken for an earthquake:

- At 5:19 pm on December 13, 2019 a large area on the Bruce Peninsula was shaken by what was initially reported as a small earthquake by Natural Resources Canada. It registered 2.1 on the Richter scale. Seismic events at that level are not usually felt, not until they reach 3.5 on the scale. But this one was felt, and heard, for several seconds from Cape Croker north-east of Wiarton, to Lion's Head, about halfway up the peninsula. The blast turned out to be from the Hunter Haulage & Excavating Inc. quarry in the Town of South Bruce Peninsula, Ontario, with the Richter scale reading revised to 1.9. The location of the blast was about 15 kilometres north of Wiarton, southwest of Hope Bay on the Georgian Bay side of the peninsula.
- In February 8, 2021, the owner of the 80.65-acre quarry (1562 Bruce Road 9, Town of South Bruce Peninsula), Hunter Haulage & Excavating Inc. pleaded guilty in Provincial Court for permitting the contravention of conditions of its licence (Scott, 2021),[71] resulting in an insignificant fine of $3,500, nothing more than the cost of doing business. "There was no blast monitoring equipment [i.e., seismographs] in position at the site, which was a permit condition to confirm compliance with blasting standards," and "the blast happened after 5 p.m., later than allowed in the site plan."

A scaled distance mathematical equation is used to predict ground vibration and airblast from blasting rock. As commonly applied in blasting rock, the calculation of scaled distance equals the distance between the blast to the point of concern (impact), measured in feet or meters, divided

[70] In *Plaunt v. Renfrew Power Generation Inc*., 2011 ONSC 4087 (CanLII) the reference to "The Law of Torts, 9th ed., John G. Fleming (Sydney: LBC Information Services, 1998), at page 48," that [i]n many American blasting cases it has been held that damage from flying rocks is trespass, but from vibration or concussion at most nuisance," no longer reflects the state of common law. Claims of damages occasioned by "vibration or concussion" as a consequence of blasting are now treated as the tort of "trespass."

[71] Dunn, S., "Company fined for Hope Bay quarry blast that shook houses," *The Sun Times*, Mar 11, 2021. <https://www.owensoundsuntimes.com/news/local-news/company-fined-for-hope-bay-quarry-blast-which-shook-houses> accessed 10 April 2023.

by the square root (for ground vibration) or by the cube root (for airblast)[72] of the charge weight of explosives per delay, in pounds or kilograms Normally, when using the equation the delay period must be at least 8 milliseconds for the sequential detonation of each blasthole. A seismograph does not measure structure response to the vibrations generated by a blast, which can be more damaging than the direct damage caused by vibrations, nor is a seismograph capable of accounting for differences in

- the footprint of a structure;
- the type of structure;
- the design of a structure;
- the age and condition of a structure;
- the type of structural materials;
- the height of a structure;
- the size and layout of a structure; or
- the contents of a structure.

In addition to variation in each of these physical variables of a structure, each structure is spatially unique (i.e., in location and distance) in relation to the blast site. Vibrations from blasting spread out in all directions from the blast site, and usually not equally so. Accordingly, the impact of blasting on every structure (and occupant) is unique, as testified to by two experts representing a quarry owner in a 2004 class action lawsuit[73] involving an estimated 11,075 people within five square miles (12.95 km^2) of the quarry:

- "*…[T]he Salter report found that "[t]he variation in noise is due to the wide range of distances between the noise sources and homes and shielding of the noise provided by natural terrain, intervening homes and vegetation. Because of these factors, in many locations, neighbours within a few hundred feet of each other have dramatically different exposure. The report notes that noise exposure also varies inside of individual homes due to the orientation of rooms, nature of furnishings, size and construction of windows and whether windows are open or closed.*"
- "*The…report, prepared by Blast Dynamics, Inc., analyzed how blasting at the Quarry affected neighbouring residents. This report identified a number of variables in the way that different residents would experience vibration from blasting. These variables include the presence of rock or soil formations that alter the frequency of blast waves, the natural or "resonant" frequencies in each structure that changes the response to vibration, distance from the blast site and differences in the duration of the blasts. The report included a geologic map of the area showing a combination of soil, rock,*

[72] Pennsylvania Blaster's License Training Manual, Department of Environmental Protection, Bureau of Mining Programs, 5600-MN-DEP4778 8/2017. <https://files.dep.state.pa.us/mining/District%20Mining/DistrictMinePortalFiles/Blasting/Blaster%20Manual%205600-MN-DEP4778.pdf> accessed 10 April 2023.

[73] *Frieman v. San Rafael Rock Quarry, Inc.* 10 Cal. Rptr.3d 82 (2004) 116 Cal.App.4th 29, <https://casetext.com/case/frieman-v-san-rafael-rock-quarry-inc> accessed 10 April 2023.

> *sandstone, artificial fill, bay mud and marshland under the relevant area. The report noted that soil typically filters out high frequency energy, while rock transmits it. Test blasts were detonated at the Quarry and instruments were placed at various locations to evaluate the differing effects. The results of the velocity measurements showed a decrease in impact with distance from the blast site, but the frequency measurements showed no consistent pattern. The report concluded that: "[t]he test data shows that it is unreasonable to expect that any two sites will experience the same blast related vibration...."*

According to Dr. Kiger, former Dean of Engineering at the University of Missouri, vibration damage from blasting is almost an absolute certainty.[74] Kiger was the expert for the Bim blasting case, which was tried in court in Boone County in March 1999. Kiger is an international expert in protecting federal buildings from blasting damage. After examining 6,000 blasting logs, he testified that there is about a 95 per cent chance of damage at a vibration limit of 0.5 inches/second (12.7 mm/sec), if you count each of the blastholes shot (50 on average) as a separate vibration. He also testified that low-frequency waves (2 Hz-11 Hz) generated by some blasts can be more damaging. The frequencies can match that of a house and amplify the shaking [p. 16]. Kiger concedes that all homes undergo daily and seasonal dimensional changes due to things like humidity variations and changing temperatures. For example, a "sticking" door that will not close or open during certain times of the year. The environmental effects will cause strains in the walls, ceilings, structural framing, the covered surfaces, etc.

These strains are known by engineers as prestrains that are strains that exist before an event like a blast-induced ground vibration. The prestrain condition may be such that a very small vibration will push the item, like a wall panel, a framing connection, or piece of tile, over its strain limit and result in a crack or loosening of a structural frame connection. It also means that:

> "*Once a crack is initiated the crack will grow at a much lower level of vibrations than was required to initiate the crack. This is because of the stress concentration that exists at the crack tip, envision for example a small crack in an automobile windshield where even a small bump from one's hand can cause the crack to grow.*"

Thus, even low levels of repeated occurrences of blast-induced ground vibrations can cause significant damage to a visible damage and cracks in masonry. For example, the German vibration standard is 0.16 ips [inches per second] [4.06 mm/sec] for buildings with visible damage and cracks in masonry. Regulatory authorities in the United Kingdom have established a peak particle velocity (ppv) of 0.24 ips; in Australia the common limit is 0.2 ips and it is 0.001 ips [0.0254 mm/sec] for historical

[74] Vivian Stockman, Ohio Environmental Coalition, *Ohio Valley Environmental Coalition v. Hobet Min*, 702 F. Supp. 2d 644 (S.D.W. Va. 2010) <https://casetext.com/case/ohio-valley-environmental-coalition-v-hobet-min> accessed 21 January 2023.

buildings and monuments for frequencies less than 15Hz.[75] The fact that these prestrain conditions can produce a condition in the home such that damage to a home will occur at even very low levels of vibrations is acknowledged in BOM [Bureau of Mines] RI 8507[76] in their Conclusion 7 [p. 68]…This conclusion, agreed to by the 4 experts that authored RI 8507 (Siskind et al., 1980),[77] clearly states that "…there may be no absolute minimum vibration damage threshold…," that is, when inevitable pre-strain conditions are present in a home, any blast induced ground vibrations might cause damage to the home.

All homes eventually crack because of a variety of environmental stresses, including humidity and temperature changes, settlement from consolidation and variations in ground moisture, wind, and even water absorption from tree roots. Consequently, there may be no absolute minimum vibration damage threshold when the vibration (from any cause, for instance slamming a door) could in some case precipitate a crack about to occur.[78] Following quote is important in this context:

> "*It is sometimes suggested that dropped weights, door slams, or foot falls will generate a ppv [Peak Particle Velocity] of 1.0 ips [25.4 mm/sec] as recorded by a nearby seismometer. While it is true that the recorded ppv may be similar to the ppv recorded for a blast generated vibration wave; the effect of these vibrations on people or homes is in no way equivalent. In fact, suggesting that vibrations created by these methods are similar to those created by a quarry blast event are very misleading and are unconvincing to any individual knowledgeable about vibration effects. While it is true that using an instrument like a seismograph to measure the peak velocity near the point of impact of a dropped weight will likely record a peak velocity similar to the peak velocity produced by quarry blast at a distant location; these vibrations are not equivalent in their effects. The ground waves generated by the quarry explosions are hundreds of feet in length and will move entire buildings as described above. The vibrations generated by dropping a weight, slamming a door, or stepping on the floor are very short in duration and in length. The localized vibrations generated by a dropped weight, door slam, or foot fall*

[75] See for example Table 1 in Konon and Schuring, "Vibration Criteria for Historic and Sensitive Older Buildings" by Konon and Schuring, ASCE Preprint 83-501; American Society of Civil Engineers (ASCE), Houston Texas, October 17-19, 1983.

[76] US Bureau of Mines RI 8507, "*Structural Response and Damage Produced by Ground Vibration from Surface Mine Blasting*," 1980. <https:// https://vibrationmonitoringcourse.com/wp-content/uploads/sites/7/2014/03/RI-8507-Blasting-Vibration-1989-Org-Scanned-Doc.pdf> accessed 21 January 2023.

[77] Siskind, D.E., Stachura, V.J., Stagg, M.S., and Kopp, J.W., "Structural response and damage produced by airblast from surface mining", US Bureau of Mine, RI 8485. <https://www.resolutionmineeis.us/sites/default/files/references/siskind-et-al-1980.pdf> accessed 21 January 2023.

[78] In Bureau of Mines RI 8507, they suggest a maximum allowable ground vibration peak particle velocity (PPV) of 0.5 inches per second (ips) or 12.7 mm/sec at which there is a 0.5 percent probability of damage. However, the standards in many other countries are much lower. For example, regulatory agencies in Leicestershire County, UK, have established the upper limit on allowable PPV as 0.24 ips (6.1 mm/sec). In Australia, the common PPV limit is 0.2 ips (5.08 mm/sec) and it is 0.001 ips (0.2 mm/sec) for historical buildings and monuments for frequencies less than 15 Hz. Frequencies less than 15 Hz are very likely in blast induced ground vibrations at large distances from the blasts.

> *generate wave with much higher in frequency and smaller length dimensions than a building and have far too low an energy level to excite an entire building. If the front door slams very hard you might hear it in the back bedroom, but the entire house will not shake.*" (Proposed Granite Quarry in Alvaton, Meriwether County, GA, 2018)

The size of the blast induced ground vibration waves shaking the homes is large in comparison to the footprint dimensions of a typical home. The length of the ground vibration wave train is the duration of the blast induced ground vibration shaking at homes, typically about 3 to 4 seconds, times the speed of the ground wave, typically about 800 ft per sec [244 metres per sec]. Thus, for a typical blasting event with multiple individual explosions the ground vibration wave train is about 3,000 ft [914 metres] long. These ground vibrations at long distances, i.e. more than 1,000 ft, [305 metres] have a dominant frequency of the ground vibration equal to about 8 to 10 Hz (cycles per sec); for a frequency of 10 Hz a single cycle of the ground shaking is 80 ft [24 metres] in length (one cycle is up down and back up) so that the leading edge of the home is picked up then pulled down while the back of the home is being picked up; this up and down of the front and then back of the house occurs repeatedly for the full 3 to 4 second duration of the ground vibration; in this example that would be about 30 to 40 complete cycles (10 cycles per second for 3 or 4 seconds). When these repeated distortions of the house match the natural frequency of the house, the motions will be amplified and damage to the house will be significantly increased.[79]

Freda Harris reached a similar conclusion finding that geological "hot spots" in a community can make vibrations from blasting worse:

> "*Freda Harris, who had a blasting case with a mine in Indiana, gathered many documents during the case and subsequent FOIAs of OSM [Office of Surface Mining]. She wrote a manual for Citizens Coal Council*.[80] *One of her most intriguing findings was that there can be "hot spots" in a community where the geography can make blasts worse. She emphasizes that damage and vibrations can feel worse if a house's natural frequency is approximately between 4 Hz and 12 Hz. The above-ground part of the house often vibrates more than the ground outside and the foundation. Yet, the DEP [Department of Environmental Protection]/OSM standard is based on ground vibration [p. 16]."*

An often-quoted blasting study (RI 8507) conducted by Siskind et al. (1980)[81] on behalf of the former United States Bureau of Mines (USBM) arguing that a vibration limit at 0.5 in/sec (12.7 mm/sec) constitutes a safe blasting limit has been criticized by other experts and successfully challenged in the courts:

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79 *Fontaina Scott v. Mountaineer Grading Co.*, Putnam Co. Vir. Act. No. 09-C-286.

80 Freda Harris and Will Collette, "The People's Guide to Blasting: How to Protect Your Home, Family and the Environment," (1999) <https://www.crmw.net/files/Blasting_Summary.pdf > accessed 21 January 2023.

81 Siskind, D.E., Stachura, V.J., Stagg, M.S., and Kopp, J.W., "Structural response and damage produced by airblast from surface mining", US Bureau of Mine, RI 8485. <https://www.resolutionmineeis.us/sites/default/files/references/siskind-et-al-1980.pdf> accessed 21 January 2023.

> "*Most of the blasting studies of the Bureau of Mines were done by David Siskind. The FOIAs provided much correspondence between Siskind and other experts, some of it quite critical. A top official of Vibra-Tech, a leader in designing blasting technology, said: "Any criteria…which ignores the frequency of a structure, and the frequency content of the ground motion is overly simplistic…Your criteria, as proposed, will neither protect the interest of the citizen and the homeowner, nor will it protect the blaster from alleged damage claims [p. 16].*"[82]
>
> "*After the Bureau of Mines was shut down by Congress [in 1996], Siskind became a private consultant. He testified for the coal company that lost the Bim case. The majority of the blasting cases have overturned his studies, and thereby the limits used by DEP and OSM. As he wrote an OSM official on June 17, 1997: "The battles I am now seeing are not 0.5 in/sec [12.7 mm/sec] versus 1.0 in/sec [25.4 mm/sec]. Complainants are trying to dismiss all the science as biased, wrong or non-applicable. For the most part, they are succeeding in ways that pay off [p. 16].*"
>
> "*Evans [an expert blaster and regional manager of explosives firm Dyno-Nobel in south-western Virginia (1982-2002)]*[83] *said they concentrate much more on the effects of the low frequencies than on per particle velocity [PPV]. The per-particle [velocity] reading almost never goes higher than 0.3 inches [per second] [7.62 mm/sec], well below the regulatory limit of 1 inch per second [25.4 mm/sec]. However, just as Sam Kiger and Freda Harris determined, the low frequencies are bothersome [p. 18].*"

The vibration levels routinely cited by the aggregate industry and its explosives engineers or blasters also overlook or ignore the following underlying critical and generic assumptions when relying on the blasting standards of the OSMB RI 8507 study conducted by Siskind et al. (1980)[84] in the preparation of a proponent-driven Blast Impact Analysis:

> "*Safe vibration levels for blasting are given in Table 13…Implicit in these values are assumptions that the structures are sited on a firm foundation, do not exceed 2 stories, and have the dimensions of typical residences, and that the vibration wave trains are not longer than a few seconds [p. 58].*"

According to Mann (2003),[85] studies published by the U.S. Bureau of Mines and the private sector have well documented the phenomenon commonly known as "frequency matching:"

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[82] Vivian Stockman, Ohio Valley Environmental Coalition, <https://www.c-span.org/person/?108142/VivianStockman>

[83] Subsequently, Evans founded Geoscan Seismic Services Inc. and is only one of four people in Kentucky currently approved to teach Basic Blaster 30-hour class, which is required by law prior to blasting on surface mines in Kentucky (Source: Geoscan Seismic Services Inc. website).

[84] Siskind, D.E., Stachura, V.J., Stagg, M.S., and Kopp, J.W., "Structural response and damage produced by airblast from surface mining", US Bureau of Mine, RI 8485. <https://www.resolutionmineeis.us/sites/default/files/references/siskind-et-al-1980.pdf> accessed 21 January 2023.

[85] Mann, M.J., "Response of Manufactured Houses to Blast Vibrations," (2003) Ohio Department of Natural Resources, Division of Mines and Reclamation, New Philadelphia, Ohio, USA. <https://files.dep.state.pa.us/Mining/BureauOfMiningPrograms/BMPPortalFiles/Blasting_Research_Papers/State%20Reports/2003%20Mann%20-2003%20BAI%20modular%20Homes.pdf> accessed 21 January 2023.

> "*If the blast vibrations contain frequencies that tend to match the "natural" frequencies at which a house "likes" to vibrate--typically in the range of 4 to 12 Hz--the house will respond significantly. The Bureau (RI 8507) recorded upper-corner responses as high as 4 times the particle velocities measured in the ground beside the houses, with 1.5 being a typical amplification factor for conventional houses up to two stories high. Because of the amplification factor and the resulting strains across interior walls, the greatest potential for damage exists when a house is vibrated at or near its natural frequency.*"

A similar criticism of PPV in measuring ground vibration levels from blasting has also been voiced in Australia. According to Jordan (2013),[86] permitted peak particle velocity (PPV) levels governed by Australian Standard AS 2187.2 (Storage and use of explosives) fail to consider the frequency or frequencies in blast vibrations and their relationship with the natural frequencies of a structure or building and the potential for damage. Even at the low Australian standards governing PPV, which are based on human perception criteria, "complaints from mine neighbours are common."

> "*Except in an informative appendix (i.e. not forming part of the standard) to the latest edition of AS 2187.2, no consideration is given in the criteria to the frequency or frequencies in the blast vibrations and their relationship with the natural frequencies of the building or structure.*"
>
> "*Resonance effects in structures are well known and form the basis for response spectrum analysis in earthquake engineering. Whilst the behaviour of whole structures is the main concern in earthquake actions analysis, the behaviour of individual elements of buildings and structures can be considered and this is applicable in determining whether, for example, a wall or ceiling panel, or even a pane of glass, may be vulnerable to damage at quite low vibration levels….[R]esonance effects measured by the author have seen PPVs amplified by factors of more than 60× [in a single charge trial blast].*"
>
> "*…PPV levels commonly applied, whilst designed to prevent damage, did not give any indications of a structure's likelihood of damage: in most cases no damage could be found at PPVs many times those prescribed, whereas at other times damage seemed to be occurring with vibrations of low PPV.*"

Jordan (2013)[87] also describes unexplainable damage to historical structures even when blasting is measured at lower PPVs of 5 mm/sec or even 2 mm/sec. He adds:

> "*In recent times there has been damage noted in some of the buildings being monitored which cannot be explained simply on the basis of the peak particle velocity [PPV] in the ground wave. In particular, cosmetic*

[86] Jordan, B., "Mine blasting vibration and its effects on buildings and structures – implementing a frequency-based approach," *Bill Jordan & Associates Pty Ltd., Newcastle NSW.* <https://aees.org.au/wp-content/uploads/2013/11/29-JORDAN-Bill-MineBlastingVibration.pdf> accessed 21 January 2023.

[87] Ibid.

> *cracking has been noted in some large ceilings when the recorded resultant PPV was close to the allowed maximum, which in itself has been set very conservatively.*"
>
> "*Elastic modelling of the ceilings and derivation of the vertical frequencies in the ground wave suggested that resonance was involved, with both ground wave frequencies and ceiling vibration modes being in the 12 Hz to 16 Hz range. In general, frequencies much above 30 Hz are usually attenuated at the typical distances between workings and sensitive buildings.*"
>
> "*It is interesting to note that individual wall panels tend to have resonant frequencies above 30 Hz, even in very large houses. Whole building vibration could be being experienced at much lower frequencies, but the difficulties of modelling such structures elastically does not give confidence in obtaining a sensible result. Even constructing a very detailed finite element model of such a building would be both costly and of doubtful accuracy.*"

Notwithstanding that placing seismographs (or any other monitoring or testing equipment) on third-party property, public or private, without authorization, is unlawful and constitutes trespass, unless a continuous string of seismographs are placed along the entire perimeter of a proposed quarry site,[88] relying on one or two seismographs to measure off-site ground vibrations in the form of (PPV) Peak Particle Velocity (longitudinal, vertical and transverse components) of the closest sensitive receptors cannot possibly be representative of the PPV level that any other sensitive receptor would experience. (Blasting seismographs usually also have a microphone attachment which can be used to measure sound from the quarry operations).[89]

The theoretical predictions of ground vibration in order to be credible would have to be measured by seismographs placed along the entire perimeter of the proponent's site to ensure that *contaminants*, as identified in the Ontario EPA, do not escape and cause external *adverse effects*. As for flyrock, the most dangerous and potentially deadly consequence of blasting, a zero policy for its prevention is essential. Complete subsurface conditions of the lands where blasting is to occur are unknowable, as are the subsoil conditions between the blast site and neighbouring private third-party properties over which a quarry owner/operator has no legal right of trespass.

Other concerns have been raised as to the relevance of seismographs, which render them ineffective in preventing adverse effects from a blasting quarry operation:

- Blasts within regulatory limits are not difficult to achieve, and seismographs can back up quarry operator claims that blasts

[88] As an example, an Irving owned company "placed nine seismographs around the site to keep tabs on vibrations from the blasting" at its quarry on the west side of the Saint John River at South Bay, City of Saint John, New Brunswick. Four seismographs were placed offsite at the homes of neighbouring residents, with the permission of the homeowners. (See CBC News article "Residents criticize Irving quarry work," August 1, 2001, <https://www.cbc.ca/news/canada/residents-criticize-irving-quarry-work-1.294598>).

[89] <https://vibrationdamage.com/vibration_monitoring.htm>.

were within regulatory limits. (Significant damage can be caused by blasts that are well within regulatory limits of a PPV of 12.5 mm per second in Ontario, Canada.)

- Peak particle velocity (PPV) levels can vary significantly from one spot to another. Quarry operators will usually try to locate seismographs away from known "hot spots" or that are likely to produce unfavourable results.
- Improper installation, use or misuse of seismographs[90]

2.4 Government Says Low Frequency and Repeated Blasting Can Cause Structural Damage

According to the Surface Mining Control and Reclamation Act (SMCRA) and F-SMRCA, low frequency blasting is problematic, and can cause structural damage, as cited in *Jarrett v. DNR* (1992),[91] and as described below:

> "*109. On one occasion, the United States District Court, Southern District of Indiana, has seen fit to reduce blasting limits in a surface coal mine blasting case. While this case originated out of a complaint for nuisance, in Massa v. Peabody, IP 88-63-C, decided August 4, 1989, Judge Tinder found that blasting with frequencies in the 4-12 Hz range was a problem and ordered a .50 ips [12.7 mm/per second] peak particle velocity limitation for any blast in the frequency range regardless of its distance from the blast.*"
>
> "*113. As with all other structures, homes have one or more natural (or harmonic or resonant) frequency. The mathematical effect of a natural frequency is that induced vibrations which are the same frequency as a natural frequency will cause vibrations to increase with time rather than decrease with time. As a practical matter, this means the midwall response of a home subjected to vibrations from a blast (or any other source) could be a displacement of up to four times the displacement at the foundation. It can also cause "racking" or shaking of the structure." See Exhibit 197.*
>
> "*114. When such a phenomena occurs, it clearly places considerable stress on the mortar between bricks, plaster walls and corners of a structure.*"
>
> "*115. Exhibit 197, OSM report RI 8507, indicates natural frequency of wood frame structures is in the 5-10 Hz range for racking. Natural frequencies of one story homes can be as high as 18 Hz, but of course the initial displacement at 18 Hz is only 1/2 of the displacement of a 9 Hz*

[90] According to a February 2023 lawsuit, after complaints to Holcim, "Holcim's Midlothian plant manager directed employees to reduce the intensity of limestone quarry blasts to create seismic data suggesting the explosions were not strong enough to cause damage or interfere with the use and enjoyment of area homeowners' property." The lawsuit accuses Holcim of gross negligence, fraud, trespass, and intentional infliction of emotional distress. <https://curated.tncontentexchange.com/partners/pr_newswire/subject/legal_issues/plant-manager-manipulated-quarry-blast-intensity-lawsuit-claims/article_cbe36cc5-0264-5020-bdd6-27230ffa94ec.html> accessed 10 April 2023.

[91] *Jarrett v. DNR and Amax Coal Company*, 5 CADDNAR 265 (1992) <https://www.in.gov/nrc/decision/89-106r.v5.html>.

> *frequency for the same peak particle velocity [PPV]. This study concludes that frequencies below 10 Hz are the most serious ones.*"
> "*116. The DNR (and NRC) has a duty to approve blasting plans which will not cause damage to offsite property.*"

Even at the court-imposed PPV limit of 0.5 inches per second (12.7 mm/sec), all structures at a long distance from the blast site will eventually experience damage from repeated blasting, which has been shown to occur at significantly lower PPVs, as low as 0.5 mm/second. PPV does not measure structural response to ground vibrations.

2.5 Contaminant Vibration and Cumulative Effect of Repeated Blasting Damaged Residence

In *R. v. Chenard* (2005)[92], the accused was charged with discharging a contaminant, namely *vibration*, from blasting explosives into the environment in contravention of Section 14(1) of the Environmental Protection Act of Ontario (EPA), R.S.O. 1990, c.E.-19[93]. The vibrations from blasting rock damaged and disrupted the use and enjoyment of the nearby Websters' property. Section 14(1) of the Environmental Protection Act sets out: "Despite any other provision of this Act or the regulations, no person shall discharge a contaminant or cause or permit the discharge of a contaminant into the natural environment that causes or is likely to cause an adverse effect."

"Adverse effect" is defined in the Act and means one or more of:

(a) impairment of the quality of the natural environment for any use that can be made of it,
(b) injury or damage to property or to plant or animal life,
(c) harm or material discomfort to any person,
(d) an adverse effect on the health of any person,
(e) impairment of the safety of any person,
(f) rendering any property or plant or animal life unfit for human use,
(g) loss of enjoyment of normal use of property, and
(h) interference with the normal conduct of business ("conséquence préjudiciable)".

"Contaminant" is defined in section 1 of the Environmental Protection Act as follows:

> "contaminant" means any solid, liquid, gas, odour, heat, sound, vibration, radiation or combination of any of them resulting directly or indirectly from human activities that may cause an adverse effect".

Chenard, a *blaster* by trade, was retained by Mr. Tulloch to excavate a trench to accommodate the installation of water and sewer lines to service a new residence on the lakefront. The Websters own the adjacent property, whose 30-year-old residence is situated approximately 114 feet (35 metres) from the blast area. Certain points are important in this regard:

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92 *R. v. Chenard*, 2005 ONCJ 501 (CanLII), <https://canlii.ca/t/1mfqs> accessed 01 April 2023.
93 <https://www.canlii.org/en/on/laws/stat/rso-1990-c-e19/latest/rso-1990-c-e19.html>

- [10] Prior to any blasting taking place, a pre-blast survey was made at the Webster residence by a contractor who identified certain damage accepted by Mr. Webster as being caused by his own personal renovations. The damage was documented.
- [11] Mr. Chenard began a series of 30 blasts through bedrock on July 17, 2001 with the last blast planned for July 25, 2001.
- [12] Because of the fact that the first 30 blasts were insufficient to accommodate the proper flow for the sewer and water line, it was necessary to perform two more blasts on September 6, 2001 [bringing the total blasts to 32].
- [13] While there was a pre-blast inspection of the Webster residence before the start of the first series of blasts, there was no pre-blast assessment prior to the commencement of the September 6 blasting.
- [15] On the 8th of September, 2001, Mr. and Mrs. Webster discovered a leak in the basement bathroom ceiling. A pipe had bust in the ceiling, water was pouring in, and it became necessary to retain the services of a local plumber on an emergency basis. Eventually the ceiling tile and the entire bathroom area had to be refinished.

Following a four-day trial, the Justice of the Peace accepted the evidence of the homeowners, which is summarized as follows:

- "*First of all, there was a vibration. Ms. Webster's evidence about the jolt she felt was credible and it was uncontradicted. She was at the best position to feel the jolt. She was standing on a floor beneath the surface of the ground, and the foundation of their home rested on the same bedrock as that being blasted. She was within 114 feet [34.7 metres] of the blasting. Also, the evidence of the boat rocking and all of the pictures being askew in the home support the finding that there was a vibration.*"
- "*The second, that the vibration was discharged into the natural environment, was also proven. Mr. Chenard put explosives into some of the holes, although not all. The Court is satisfied that Mr. Chenard discharged the contaminant, that being the vibration, into the natural environment.*"
- "*Number three, that there was an adverse effect. The Court is satisfied that there was an adverse effect. There were numerous damages to the Webster home. Two days after the blast of September 6 the Websters found a major repair that they had to do in their basement bathroom.*"

While the homeowners' evidence was accepted by the Justice of the Peace, she had concluded that the discharge of the *vibration* contaminant occasioned by the blast on September 6, 2001 had not been proven as the cause of the *adverse effect* (i.e., damage to, and disruption of use and enjoyment of the Websters' residence). Following statement is noteworthy:

> "*Finally, and this is the element that was not proven, the discharge of the contaminant on September 6 [, 2001,] caused the adverse effect. There was little evidence to support a finding that the Websters' loss of*

> *enjoyment of normal use of their property was directly attributable to the blast that was the substance of the charge. Witnesses describe the September 6th blast as the largest blast. However, they also admitted that their comparison took into account the fly rock that they saw, the blasting mats lifting off the blast area, and the sound of the explosion. The only witness who felt the actual vibration was Mr. Webster.*"

The Crown appealed the ruling of the Justice of the Peace to the Ontario Court of Justice, and, while the appeal court accepted the findings of the Justice of the Peace, the appeal court concluded that the trial court failed to consider the secondary aspect: "or was likely to cause an adverse effect." In defining the term "likely," the appeal court relied on the following:

> *[40] The word "likely" carries with it a tremendous amount of responsibility to the trier of fact and to any appellate review. In Black's Law Dictionary (Fourth Edition) it equates to "probable" and "in all probability". In the Oxford Illustrated Dictionary "likely" is referred to as "probable" and "such as may well happen".*
>
> *[41] In the case of R. v. Walter Wood (28 April 1987), Provincial Offences Court, [unreported], a decision by Justice of the Peace W. G. Jacklin, he refers to R. v. Carbone, 1973, 20 Criminal Reports, New Series, 313, relating to substantial likelihood.*

The learned Judge in dealing with substantial likelihood:

> *"Does not mean proof beyond a reasonable doubt, but is 'more akin to the balance of probabilities in that the evidence should substantially weigh in favor of the likelihood of a repetition of the offence."*
>
> *Here, we're dealing with likely. I am of the opinion that in fact likely is something less than substantial likelihood. It has been found that substantial likelihood is akin to the balance of probabilities and in the matter of Labatt Breweries of Canada Limited, it connotes a probability.*
>
> *[42] Also,*
>
> > *Dealing with the issue under Regina v. Toronto Refiners and Smelters, the Ontario High Court of Justice,[1977][94] the Divisional Court, Volume 20, Ontario Reports, 2nd Series, at page 772. At page 774.*

The questions stated should be determinative of the issue before the Court. It is argued by the respondent that the words "causes or is likely to cause harm or material discomfort to any person" are descriptive of the contaminant. In our view, in order to succeed, it must be shown that the contaminant did in fact cause or was likely to cause, in the circumstances that existed, harm or material discomfort to a person.

In reversing the judgment of the lower court, the Ontario Court of Justice found that the Justice of the Peace had failed to consider the words "or was likely to cause an adverse effect" or to consider "the accumulative effect of all 32 blasts":

> *[43] Based on the evidence that was adduced during the course of the four day trial, it is evident to me that the Justice of the Peace did not*

[94] *Regina v. Toronto Refiners and Smelters Ltd.*, 1977 CanLII 1299 (ON SC), <https://canlii.ca/t/g16cv> accessed 10 April 2023.

> *consider the words "or was likely to cause to an adverse effect" or to consider the accumulative effect of all 32 blasts, including those on 6th of September, 2001.*

As for the accumulative effect of repeated blasting, in *Whitney v. Ralph Myers Contracting Corp.*, (1961),[95] the Supreme Court of Appeals of West Virginia reached a similar conclusion, where it held:

> "*Plaintiffs were not required to show that the damages to the basement walls were the result of any particular or isolated explosion, but only to establish facts that would fairly raise an inference to the cause thereof. That repeated vibrations of the earth, at or in the vicinity of plaintiffs' property, occasioned by the blasting operations, occurred during times material, appears to be clearly established by the proof and, we believe, the evidence sufficiently establishes that the damage to the basement walls did not occur because of normal pressures or circumstances.*"
>
> "*Several witnesses testified to the nature and severity of the vibrations resulting from the blasting operations of defendant, which reach the plaintiff's property and its vicinity, and of complaints made to defendant relating thereto.*"

In this case, the Whitney residence was relocated on January 15, 1959 and placed on a new concrete block basement foundation (cinder blocks eight inches wide, eight inches high and sixteen inches long) to facilitate acquisition of the right-of-way for new Interstate Highway No. 64. A deep cut through an elevation of the right-of-way required breaking of rock, which was accomplished by detonation of explosives. The Whitney residence was relocated a distance of approximately 1,800 feet (549 metres) from the nearest point of the blasting operation. After the Whitneys reoccupied the house, cracks began to appear in the basement walls and continued to increase in number and size until April 10, 1959, when the basement walls, or, at least, the largest part thereof collapsed, causing the house to fall. No witness observed any cracks or breaks in the basement walls appear simultaneously with experiencing any ground vibrations. Nonetheless, on the claim of trespass, the Whitneys were awarded $1,288.95 for the damages to the basement walls caused by ground vibrations from the use of explosives, an extremely dangerous undertaking. As noted by the appeal court,

> "*The use of dynamite in blasting is a well-recognized practice, but the injurious results often occasioned thereby are equally well known. Any person who uses it in such manner as to cause damage to his neighbour must be held absolutely liable therefor.*[96]
>
> *We can see no reason for imposing a different liability for the results of an explosion, whether the dynamite explodes when stored or when employed in blasting. To be sure there is a greater likelihood of damage*

[95] *Whitney v. Ralph Myers Contracting Corporation*, 118 SE 2d 622, 146 W Va Supreme Court of Appeals, 1961, <https://www.casemine.com/judgement/us/59149cdfadd7b049346490ef> accessed 10 April 2023.

[96] See Exner v. Sherman Power Construction Co., 2 Cir., 54 F.2d 510, 80 A.L.R. 686; Weaver Mercantile Co. v. Thurmond, 68 W.Va. 530, 70 S.E. 126, 33 L.R.A.,N.S., 1061; Wigal v. City of Parkersburg, 74 W.Va. 25, 81 S.E. 554, 52 L.R.A.,N.S., 465; Dallas v. Whitney, 118 W.Va. 106, 188 S.E. 766. In the Exner case, supra, the Court, by Judge Augustus N. Hand, stated [54 F.2d 514].

> *from blasting than from storage, but in each case the explosion arises from an act connected with a business conducted for profit and fraught with substantial risk and possibility of the gravest consequences*."[97]

The research conducted supports the finding that quarry blasting conducted within regulatory limits does not eliminate property damage from ground vibrations or airblast, and has a negative impact on health and quality of life of residents in nearby communities. The standard response from quarry operators to complaints from residents of communities impacted by blasting is that "the quarry is operating within regulatory limits" and, thereby, avoid acknowledging and accepting legal responsibility for payment of damages. It was emphasized:

> "*Various sources of vibrations are involved in construction and mining projects such as blasting, heavy equipment, pile driving and dynamic compaction. Elastic vibrations that are generated by these sources may harmfully affect the nearby residential areas. Their effects include annoyance of people and cosmetic and structural damage to the buildings [p. 1]*".[98]

2.6 No Safe Level of Vibration for Threshold Damage to Nearby Structures from Blasting

The susceptibility of a structure or dwelling to damage from blasting depends on vibration levels, Peak Particle Velocity (PPV)[99] excitation frequencies [frequency at which body is made vibrate in forced vibration], and related site and structure factors (Singh and Roy, 2010),[100] and there is no absolute minimum vibration damage threshold whereby blasting or environmental or occupant-related vibration could precipitate a crack.[101] Further explanation is as under:

> "*…The threshold level of cracking is highly dependent on the level of residual stresses present that may reduce the apparent PPV level causing damage. It is widely accepted among blast researchers that the lengthening of old cracks and formation of superficial "hair-sized new cracks constitutes a threshold damage level (Rainer, 1982;*[102] *Northwood*

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97 See *Wilson v. Phoenix Powder Manufacturing Co*., 40 W.Va. 413, 21 S.E. 1035, 52 Am.St.Rep. 890.

98 "A Case Study of Blast Vibration Modelling in The Hanason Servtex Quarry, Garden Ridge City, Texas," A Thesis by Mohamed Mahmoud Ahmed Radwan, Texas A&M University, December 2016. <https://oaktrust.library.tamu.edu/handle/1969.1/159103?show=full> accessed10 April 2023.

99 The maximum velocity amplitude (rate of displacement change with respect to time, measured in mm/sec) with which a particle would travel due to propagation [detonation of explosive charge] through the ground. Seismographs are used to measure the PPV.

100 Singh, P.K. and Roy, M.P., "Damage to surface structures due to blast vibration," (2010) 47 (6) International Journal of Rock Mechanics and Mining Sciences949-961. <https://www.sciencedirect.com/science/article/abs/pii/S1365160910001073> accessed 10 April 2023.

101 Heath, D. J., Gad, E. F. and Wilson, J. L., "Vibration and Environmental Loads Acting on Residential Structures: State-of-the-Art Review," (2015) American Society of Civil Engineers.

102 Rainer, J.H., "Effect of vibrations on historic buildings: an overview," (1982) 14 (1) Bulletin of the Association for Preservation Technology 2-10. <https://nrc-publications.canada.ca/eng/view/ft/?id=c60d365a-a3c7-4c3f-b8de-4b205aec9d2c> accessed 10 April 2023.

> *et al., 1963;[103] Singh and Roy, 2010;[104] Siskind et al., 1980;[105] Stagg et al., 1984;[106] Dowding, 1996).[107] Few publications present observations of damage and corresponding ground motion measurements. Dowding (1996)[108] notes the only definitive method of correlating the incidence of cracking with blast vibrations is to conduct a pre- and post-vibration crack survey, which will also reduce complaints and lawsuits. The identification of an appropriate limit unlikely to cause any damage is made all the more difficult by the presence of residual stresses, particularly older structures, resulting from settlement, poor maintenance, weather cycles, and prior repair and renovation (Konon and Schuring, 1983).[109] For this reason, Siskind et al. (1980)[110] note there may be no absolute minimum vibration damage threshold whereby blasting or environmental or occupant–related vibration could precipitate a crack."*

Granular soils (sands and gravels) are also susceptible to vibration-induced damage in the form of densification (increased soil density or compaction of unconsolidated soils from blasting and removal of air voids) as described in Structural Forensics Technical Note #105 (Origin and Cause, July, 2021) at vibration levels as low as 0.5 mm/second (Siskind, 2000),[111] far below the maximum permitted Ontario Provincial standard of 12.5 mm/ second (Model Municipal Noise Control Bylaw NPC-119). Following point is noteworthy:

> *"…[G]ranular soils (sands and gravels) are susceptible to vibration-induced densification at vibration levels as low as 2.5 mm/s PPV (Lacy and Gould, 1985).[112] Such vibrations can lead to significant foundation*

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[103] Northwood, T.D., Crawford, T.D. and Edwards, A.T., "Blasting vibrations and building damage," (1963) 215 (5601) Engineer 973-978. <https://nrc-publications.canada.ca/eng/view/ft/?id=ed987490-420b-429d-85a8-00de96ec260d> accessed 10 April 2023.

[104] Singh, P.K. and Roy, M.P., "Damage to surface structures due to blast vibration," (2010) 47 (6) International Journal of Rock Mechanics and Mining Sciences949-961. <https://www.sciencedirect.com/science/article/abs/pii/S1365160910001073> accessed 10 April 2023.

[105] Siskind, D.E., Stachura, V.J., Stagg, M.S., and Kopp, J.W., "Structural response and damage produced by airblast from surface mining", US Bureau of Mine, RI 8485. <https://www.resolutionmineeis.us/sites/default/files/references/siskind-et-al-1980.pdf> accessed 10 April 2023.

[106] Stagg, M.S. and Engler, A.J., "Measurement of Blast-Induced Ground Vibrations and Seismograph Calibration," (1984) Report of Investigations 8506, US Department of Interior. <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=41c42eed489376b182c93dfcc0afd7b47070ca00> accessed 10 April 2023.

[107] Dowding, C.H., "Construction Vibrations," Prentice Hall, 1966, <https://books.google.ca/books?redir_esc=y&id=w4lGAAAAYAAJ&focus=searchwithinvolume&q=pre>

[108] Ibid

[109] Konon and Schuring, "Vibration Criteria for Historic and Sensitive Older Buildings," ASCE Preprint 83-501; American Society of Civil Engineers (ASCE), Houston, Texas, October 17-19, 1983.

[110] Ibid, n.105

[111] Siskind, D.E., 'Vibration from blasting', (2000) International Society of Explosives Engineers, Cleveland, OH, USA.

[112] Lacy, H.S. and Gould, J.P., "Settlement from pile driving in sands," (1987) 24 (6) International Journal of Rock Mechanics and Mining Sciences 233.

settlement if the foundation is bearing on loose or poorly compacted sand. Siskind (2000)[113] found that loess[114] soils may sometimes be even more sensitive to vibration-induced settlement, and reported that damage had occurred from blasting operations at PPV of just 0.5 to 1.5 mm/s."

2.7 Ontario Municipalities Can Enact Noise and Nuisance By-laws to Protect the Health, Safety and Welfare of the Public From the Adverse Effects of Aggregate Extraction

Under the Ontario Municipal Act, 2001, as amended,[115] municipalities can prohibit noise and vibrations that are likely to disturb the peace, rest and quiet living spaces, including outdoor recreational and amenity space, of residents. Municipalities have the authority to create and enforce bylaws that control or prevent noise disturbances.

According to the Province of Ontario, "noise pollution is any form of sound that disrupts a natural ecosystem or causes a person's property to become unusable or unpleasant" or that impacts your quality of life,[116] Noise pollution can have negative impacts (adverse effects) on human health, especially children, including:

- loss of sleep
- loss of concentration
- increased stress and anxiety levels
- hearing loss
- high blood pressure
- heart disease.

The province of Ontario does not have jurisdiction over municipal bylaws provided that the municipal bylaw does not conflict with guidance provided by the Environmental Protection Act (EPA). An "Ontario Model Municipal Noise Control Bylaw" is available online.[117] [See Publication NPC-119 for Blasting in quarries and surface mines.] A municipality is empowered to enact and implement a noise and nuisance bylaw under the Municipal Act, that offers a greater degree of health and safety, similar in substance to the one passed by the City of Burlington, which prohibits *noise and vibrations* to be heard or felt outside of the property of a blasting (or non-blasting) quarry operation. The City of Burlington Noise and Nuisance bylaw (No. 19-2003),[118] in part, states,

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<https://www.sciencedirect.com/science/article/abs/pii/0148906287924041?via%3Dihub> accessed 10 April 2023.

113 Siskind, D.E., 'Vibration from blasting', (2000) International Society of Explosives Engineers, Cleveland, OH, USA.

114 Loess soils are composed primarily of silt particles deposited by wind.

115 Municipal Act, 2001, S.O. 2001, c. 25, as amended. <https://www.ontario.ca/laws/statute/01m25>.

116 Environmental Noise Guideline – Stationary and Transportation Sources – Approval and Planning (NPC-300). <https://www.ontario.ca/page/noise-our-environment>

117 Ontario Model Municipal Noise Control By-law, <https://jcaa.caa-aca.ca/index.php/jcaa/article/view/374/34>

118 The Corporation of the City of Burlington By-law No. 19-2003, "The Nuisance and Noise Control By-law," <https://www.burlington.ca/en/by-laws-and-animal-services/resources/By-laws/By-law-Search/019-2003-By-law.pdf>

> "*No noise or vibrations shall be made, caused or created so as to be heard or felt or otherwise perceived outside the property and which are, in the view of all the circumstances including the nature of the neighbourhood and the use to which adjoining properties are put and the time of day during which such noise or vibrations are made, caused or created excessive or which are, or may cause a nuisance to the public generally or to others residing or carrying on a manufacture, trade or business in the vicinity.*"[119]

2.8 Noise Pollution Impacts on Non-human Life

Like humans, domestic animals are clinically affected by rock-blasting, as testified to by Dr. Lisa Dietrich (Public hearing July 13, 2015) in the application for a permit by Tory Sand & Gravel submitted to the Town of Nassau. Following is the testimony of Dr. Dietrich:

> "*…Testimony from Veterinarian Dr. Lisa Dietrich…indicates that domestic animals are clinically affected by dust, allergens and other irritants that may result from blasting at the quarry, and suffer stress from anxiety related to equipment and blasting noise. We think that those same things could also cause safety concerns for the handlers of the animals. It is reasonably foreseeable that there could be impacts on domestic animals which could result in added expenses for the household, lower the animal's quality of life, and as related to agriculture, reduce farming and agri-tourism opportunities.*"

Noise pollution also impacts the health and well-being of wildlife. Studies have shown that loud noises can cause caterpillars' dorsal vessels (the insect equivalent of a heart) to beat faster, and cause bluebirds to have fewer chicks. Animals use sound for a variety of reasons, including to navigate, find food, attract mates, and avoid predators. Noise pollution makes it difficult for them to accomplish these tasks, which affect their ability to survive (National Geographic, Resource Library).[120]

2.9 Strict Liability Extends to Ground Vibrations and Concussions (Airblast) from Blasting

A number of jurisdictions have reached the conclusion that indirect impacts such as *Airblast (Concussion)* and *ground vibrations* stemming from blasting rock with explosives are just as much an invasion of public and private third-party property as if struck directly by flyrock, with all three impacts emanating from the same event (i.e. detonation of explosives to break rock) held to strict liability.

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[119] *Nuisance* is "the unreasonable, unwarranted and/or unlawful use of property, which causes inconvenience or damage to others, either to individuals and/or the general public. Nuisances can include noxious smells, noise, burning, misdirection of water onto other property…and a host of bothersome activities. Where illegal they can be abated (changed, repaired or improved) by criminal or quasi-criminal charges. If a nuisance interferes with another person's quiet or peaceful or pleasant use of his/her property, it may be the basis for a lawsuit for damages and/or an injunction ordering the person or entity causing the nuisance to desist (stop) or limit the activity (such as closing down an activity in the evening)." ALM Law.Com Dictionary. <https://dictionary.law.com/Default.aspx?selected=1358>.

[120] "Noise Pollution," <https://education.nationalgeographic.org/resource/noise-pollution> accessed 10 April 2023.

In *Aikman v. George Mills & Co. Ltd. et al.* (1934),[121] the trial judge held that ground vibrations from blasting to deepen the Livingstone Channel in the Detroit River caused damage to the Aikman Residence in Amherstburg, Ontario, a ruling which was upheld on appeal to the Ontario High Court of Justice. The Aikmans' residence, newly constructed in 1931, located about 3,500 feet (1,067 metres) from the closest point at which work was commenced by George Mills & Co. in 1932. Both George Mills & Co. and the blaster (Arundel Corporation) were found strictly liable for the damage done by the escaping vibrations, pursuant to the rule of *Ryland v. Fletcher* (1868), L. R. 3 H.L. 330, and held jointly and severely responsible for the full amount of the damages awarded by the court to Aikman. The court explained:

> "*The first of the work in the channel with which we are concerned in this case was done by the defendants George Mills & Company on section B. The method followed on this section was spoken of as the "dry" method. Coffer-dams were built…around the part of the channel that was to be deepened, the area was dewatered, and the rock was blasted away to the required depth. The first blasting was done on December 17, 1932, and there was blasting on many later days in December; but the charges of explosion used were relatively small, and it was not until January 11, 1933, that any charge was used that, on the evidence, can reasonably be found to have been heavy enough to cause damage to the plaintiff's house. On January 11 there were two blasts in each of which more than 2,000 lbs [907 kilograms] of dynamite were used; and from that time until August 2, blasts of that magnitude were of very frequent occurrence…. The heaviest seems to have been on July 18, when 5751 lbs [2,609 kilograms] were used. After August 2 there were only (relatively) light blasts on any part of the work until the Arundel Corporation began work in section C. on September 27. From that time until the end of October there was blasting in section C. almost daily, on some days several blasts, until the latter part of October; but the work on this section was done under water, the drills being operated from scows, and the area blasted, and consequently the quantity of dynamite used, in any one blast being less than in the "dry" work done in section B. On only three occasions was as much as 2,000 pounds [907 kilograms] of dynamite exploded at one time; but explosions of 1,500 or 1,600 pounds [726 kilograms] weight were frequent.*"

Mr. Aikman described the extent of the damage to his home as follows:

> "*…[I]n the summer he found some 200 cracks, of which seventeen were in the foundation where he had found two on his first examination and one was in the stone work; that in November there were twenty cracks in the stonework, and that all cracks had opened considerably; that he glued strips of paper across some of the cracks and a fortnight later found some six or eight of these strips broken. He says that on one occasion a crack appeared at the moment of a blast and that on another occasion some*

[121] *Aikman v. George Mills & Co. Ltd. et al*., 1934 CanLII 99 (ON SC), <https://canlii.ca/t/g1g6g> accessed 10 April 2023.

> *article was jolted from a shelf in the kitchen. Both he and the plaintiff swear to the trembling of the house at the time of blasts, and the plaintiff speaks of windows and dishes rattling*."

While the Aikmans' evidence of damage lacked some specificity, other homeowners in the area were able to corroborate the timing of various blasts and the impact on their homes. The writ described that:

> "*Neither the plaintiff nor Mr. Aikman gives any very precise evidence as to the time of the appearance of the several signs of damage; but a witness, Mrs. Teeter, who lives in the neighbourhood and who, apparently, has in contemplation a claim for damage done to her house, had kept some notes and was able to tell of the rattling of the crystals of a lamp, almost at the moment of the explosion of a heavy charge of dynamite by George Mills & Company on April 20, and of the appearance of a crack in one of the walls of her house at the time of the firing of a much lighter blast (2,027 lbs.) [919 kilograms] on February 20; and Mrs. Wilson, who is not a claimant but is tenant of an old and solidly constructed building tells of much damage caused and of vibration at the time of blasts sufficient to shake articles from a table and a picture from its place; and other witnesses give evidence upon which it is perfectly certain that houses in Amherstburg were shaken by the blasts and were to a greater or less extent damaged*."

As to the cumulative effect of repeated blasting on the Aikmans' residence, the Ontario High Court of Justice had this to say:

> "*The fact is, however, that what the plaintiff sues for is not the damage done to a wall by a certain blast, to a chimney by another, to the foundations by a third, and so on, but for the damage done to the house as a whole by the whole series of blasts, and that a finding that any part, or any definable part, of that damage was caused by the blasting done by the Arundel Corporation in section C. (where no very heavy charges were used;…) would be speculative in the extreme. Indeed, it is probably correct to describe the plaintiff's house in its present condition as a house the fabric of which has suffered from the cumulative effect of a series of shocks, rather than as a house in which there are many defects each of which is attributable to a shock*."

The judge was unimpressed by the superficial and theoretical nature of the evidence presented by the defendant's expert, saying that:

> "*The impression created by the evidence was that such investigation as there was superficial, and that there was too much reliance upon theoretical opinion*."

And, while it was possible that shrinkage could cause damage to the Aikmans' residence, the judge favoured the expert opinion of Mr. Allan, testifying on behalf of the homeowners, who found no indication of shrinkage. He lamented that:

> "*…I have come to the conclusion that it is safe to adopt the opinion expressed by Mr. Allan when called in reply and cross- examined, to the effect that while it cannot be said that there was no shrinkage of timber, or no cracks caused by shrinkage, it can be said that more than half of the cracks are attributable to something other than shrinkage. Mr. Allan*

> *would not swear positively that it was impossible that 90 per cent. of the cracking had been caused by shrinkage; but he said that he could find no evidence of shrinkage, and, as has been stated, that he believed that the greater part of the cracking seen must be attributed to another cause. It cannot be found that there had been any settlement (or unusual settlement) of the house; and, as I have said, my conclusion is that the opinion that at least the greater part of the damage was caused by the blasting is well supported by the evidence.*"

In *J. P. Porter Co. v. Bell et al.* (1954),[122] the Nova Scotia Court of Appeal upheld the trial court's ruling that Porter was responsible for structural damage from ground vibrations to three dwellings distant 1,430 feet (436 metres), 2,250 feet (686 metres) and 2,275 feet (693 metres) from where Porter conducted 198 blasts during the period of August 15, 1951 to April 3, 1952. Porter was found strictly liable for the damages caused to the Plaintiffs' houses by the escaped vibrations under the rule of *Rylands v. Fletcher*. The court maintained:

- "*From August 15, 1951, to April 3, 1952, inclusive, the defendant engaged in blasting and dredging operations at the Seaward Defence Site; but its blasting operations ceased on February 2, 1952. From this site the houses of the plaintiffs Bell, Overstone and MacDonald were situated westwardly about 1,430, 2,250, 2,275 ft, [693 metres] respectively.*"
- *According to the trial Judge "the rock being blasted and removed was of sedimentary origin and was stratified formation and that same formation extended westerly from the point of blasting to and beyond the location of the plaintiffs' houses and dipped about 10 degrees toward the west. This stratified rock was broken or cracked approximately at right angles to the dip at various intervals."*
- "*There is no doubt that the detonation of the dynamite during the period in question in 198 blasts, comprising a total of 38,343 pounds [17,392 kilograms] of explosive, did cause vibrations in the submarine rock which extended to the adjoining land-rock formation and caused the houses to vibrate.*" *["The individual blasts involved the detonation of dynamite in amounts ranging from 15 to 720 lbs.] [327 kilograms in drill-holes ranging in number from 1 to 12."]*
- *The first essential question, whether the blasts and the resultant vibrations caused the damage complained of, was answered by the trial Judge, after an exhaustive examination of direct and opinion evidence, as follows: "I accordingly find that each of the plaintiffs' houses was substantially damaged by their vibratory motion which was in turn caused by the rock vibrations originating at the defendant's blasting operations and transmitted through rock from the point of origin to the rock beneath the houses on which they stood." In evaluating the weight of this evidence he was quite justified in preferring the former.*

[122] *J. P. Porter Co. Ltd. v. Bell et al*., 1954 CanLII 303 (NS CA), <https://canlii.ca/t/gwcvk> accessed 10 April 2023.

- "*In my opinion there was ample evidence to support this conclusion on the issue of causation in fact. The trial Judge was faced with evidence which on this issue consisted "of what a large number of credible witnesses actually saw, felt and heard" supported by competent opinion evidence on the one hand; and of competent opinion evidence to the contrary effect on the other hand.*"

In *Enos Coal Mine v. Schuchart et al.* (1963),[123] the Indiana Supreme Court ruled there is no logical reason not to extend strict liability for property damage from *vibrations* simply because there is no physical trespass as in falling debris (flyrock) from an explosion on nearby land. The court ruled that the common law principle of liability in trespass applies equally where damage is caused only by *vibration*, commenting by way of analogy, as follows:

> "*In these days of nuclear explosions, the breaking of sound barriers by airplanes and missiles, violent explosions from artillery and gunnery practice (to mention but a few of the advances of science), nearby buildings and property can be shattered or destroyed as effectively as by an earth quake without any physical invasion of the property.*"

The United States Supreme Court has recognized these modern problems in holding that property owners are entitled to compensation for deterioration in property values caused by noise and vibration of jet planes in the use of air space near an airport. Griggs v. Allegheny County (1962), 369 U.S. 84, 82 S.Ct. 531, 7 L.Ed.2d 585. In *Spano v. Perini Corp.* (1969),[124] the Court of Appeals of New York declared that "one who engages in blasting must assume responsibility and he is liable without fault for any injury he causes to neighbouring property." The Spano Court overturned the need to prove *negligence*[125] for non-trespassory blasting damages for the following reasons:

1) Existing and out-of-state court decisions use strict tort liability for construction blasting;
2) Individual property rights are a concern;
3) Strict tort liability is used for accidental explosions;
4) It is difficult to prove negligence in blasting cases;
5) Blasting involves a substantial risk of harm; and
6) It is problematic to determine which party should bear liability for blasting damages [p. 209].[126]

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123 *Enos Coal Mining Company v. Schuchart et al.*, 243 Ind. 692 (1963) 188 N.E.2d 406, <https://casetext.com/case/enos-coal-mining-co-v-schuchart-et-al> accessed 10 April 2023.

124 *Spano v. Perini Corp.*, 25 N.Y.2d 11 (1969), <https://www.lexisnexis.com/community/casebrief/p/casebrief-spano-v-perini-corp> accessed 10 April 2023.

125 A claimant must prove (4) elements to have a successful negligence claim in New York state. The elements to a negligence case are duty, breach of duty, causation, and damages. <https://lawsuit.org/personal-injury-law/torts-law/new-york-negligence-guide/> accessed 10 April 2023.

126 Stark, T.D., "Is Construction Blasting Still Abnormally Dangerous?," (2010) 2 (4) Journal of Legal Affairs and Dispute Resolution in Engineering and Construction <https://www.researchgate.net/publication/245492954_Is_Construction_Blasting_Still_Abnormally_Dangerous> accessed 10 April 2023.

In *Wiley v. Pittsburg & Midway Coal Min. Co.* (1987),[127] the Missouri Court of Appeals acknowledged that damage to property by *concussion* or *vibration* from blasting must be demonstrated by circumstantial evidence *because the concussions or vibrations that travel through the air or the earth cannot be seen.*[128] It is substantiated as:

> "*From cases such as* Summers v. Tavern Rock Sand Co., 315 S.W.2d 201 (Mo.1958)[129], *it appears that a submissible case for damages caused by blasting may be made on testimony that vibrations were felt coincidentally with the detonation of the explosive and that physical evidence of structural damage was observed thereafter. Thus, in the present case, plaintiffs' testimony of the vibrations sensed, corroborated by the calendar diaries, and the perceived cracks in walls and floors was enough at least to survive a motion at the close of plaintiffs' evidence.*"

In *Frye et al. v. Kanawha Stone Co., Inc.* (1998),[130] in upholding the decision of the lower court, the West Virginia Supreme Court of Appeals ruled that vibrations from blasting were the proximate cause of damage to the Fryes' home. In 1992 and 1993, construction for the upgrading of a highway near the Frye residence, and blasting operations continued on an intermittent basis from late 1992 until at least June 1993. On May 25, 1993, Kanawha Stone detonated an explosive blast at a distance of 962 feet (293 metres) from the Frye residence, which caused the following damage:

> "*The blast, like most large explosions, rattled windows and cabinets in the Frye home and in other homes in the Fryes' neighbourhood. Mr. Frye had a habit of going out after each large detonation to inspect for damages to his property, due to the proximity and severity of the blasting. On this occasion, he claimed that numerous cracks suddenly appeared in the mortar joints and blocks of his home's cinder block walls.*"

A seismographic record of soil vibration on each blast was kept by Kanawha Stone. That the soil vibration measured for the May 25, 1993, blast "was well below any state imposed limits" and supporting testimony of the blasting expert that the recorded vibrational level was insufficient to have caused any damage to the Frye home was rejected in favour of the corroborating evidence of the neighbours who had observed the cracks. The Fryes were awarded $20,000, allocating $10,000 for costs and repairs and $10,000 for annoyance and inconvenience.

In *Associated Contr. Stone v. Pewee Val. San. & Hosp.* (1963),[131] the Kentucky appellate court upheld the lower court's injunction preventing a

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[127] *Wiley v. Pittsburg & Midway Coal Min. Co*., 729 S.W.2d 228 (1987), <https://cite.case.law/sw2d/729/228/> accessed 10 April 2023.

[128] *Donnell v. Vigus Quarries, Inc.*, 526 S.W.2d 314, 316 (Mo.App.1975); *Poston v. Clarkson Construction Co.*, 401 S.W.2d 522, 525 (Mo.App.1966). <https://scholar.google.ca/scholar_case?case=11912900217179761342&hl=en&as_sdt=2006> accessed 10 April 2023.

[129] <https://scholar.google.ca/scholar_case?case=16366987539217898125&hl=en&as_sdt=2006>

[130] *Clarence Frye, et al. v. Kanawha Stone Company, Inc.*, 505 S.E. 2d 206 (1998) 202 W.Va. 466, <https://case-law.vlex.com/vid/frye-v-kanawha-stone-885869106> accessed 10 April 2023.

[131] *Associated Contr. Stone v. Pewee Val. San. & Hosp.*, 376 SW 2d 316 (1963), <https://law.justia.com/cases/kentucky/court-of-appeals/1963/376-s-w-2d-316-1.html> accessed 10 April 2023.

proposed quarry from being established a short distance southeast of the City of Pewee Valley, in a rustic neighbourhood with no industry and no public water supply. The suit to prevent operation of a blasting quarry was brought by over 50 parties, with proof clustered along three salient issues:

1) Lowering of the "water table" likely to result from drainage of underground waters, by force of gravitation, to and out of the face of the quarry when the rock formations are cut open;
2) Damage to the natural water supply through disturbance, by the use of explosives at the quarry, of underground barriers that now serve to impound the water; and
3) Disruption of the peace and quiet by vibrations from blasting.

Apart, however, from the water phase of the case, there is other and more positive proof that the operation of the quarry will materially affect the peace and quiet of the neighbours in the enjoyment of their homes. It so happens that before the institution of this proceeding the defendants set off at the quarry site a 2,000-lb.[907 kilograms] test charge of dynamite, a quantity they admit to have been substantially smaller than they expect to use routinely. This blast was heard and the tremor felt by several of the plaintiffs in their homes nearby. One said that his television set, the chimney, and "every window in the house" shook. Another said the noise caused his wife to jump up and scream and the concussion "actually blew the curtains out." Some of the plaintiffs live directly across the road from the quarry property. If their homes were shaken by the test shot, it is certain that they would be repeatedly shaken by the larger shots expected to be used in the regular course of business. We think this is an interference they should not be forced to suffer. [Kentucky has expressly renounced the 'negligence theory' *Island Creek Coal Co. v. Rodgers*, (1982),[132] in blasting cases; as 'blasting' is an activity which has repeatedly been held to strict liability.]

The Kentucky appeal court concluded that the rule of nonliability for damage by *concussion* or *vibration* is inconsistent with the principles set forth in Louisville Refining Company v. Mudd, Ky. 1960, 339 S.W.2d 181,[133] for the determination of what is a nuisance. The appeal court held that the lower court's finding that "a nuisance necessarily would result was not clearly erroneous," as supported by the stipulations and admissions of the defendants:

> "*…[B]y their own stipulations and admissions during the course of trial the defendants left no room to suppose that they could or would conduct their operations in any manner or on any scale that would not involve a shaking of the environs occupied by the plaintiffs. Their case was honest and forthright. They made no pretence that this particular result would not be a necessary incident of their business as they intended to operate it.*"

[132] *Island Creek Coal Co. v. Rodgers*, 644 SW 2d 339, Ky. Court of Appeals, 1982.
[133] *Louisville Refining Co. v. Mudd*, 339 S.W.2d 181 (Ky. Ct. App. 1960) <https://casetext.com/case/louisville-refining-company-v-mudd> accessed 10 April 2023.

As noted in the Northern Kentucky Law Review (Vol. 8/323), in reference to an Ohio case, *Louden v. City of Cincinnati*, 90 Ohio St. 144 (1914),[134] involving property damage caused by *concussions* and *vibrations* from blasting,

> "*If the means employed [blasting] will, in the very nature of things, injure and destroy his neighbour's property, notwithstanding the highest possible care is used in handling of the destructive agency, the result to the adjoining property is just as disastrous as if negligence had intervened. If one may knowingly destroy his neighbour's property in the improvement of his own, it is little consolation to the neighbour to know that his property was destroyed with due care and in a scientific manner [p. 334]*".

2.10 Every Property Near a Quarry is Uniquely Impacted by Blasting

In *Freeman v. San Rafael Rock Quarry Inc.* (2004),[135] pursuant to a June 2001 Marin County (California) Grand Jury report, which was critical of the county's handling of complaints about the quarry and recommended the district attorney institute a nuisance abatement action against the quarry, the homeowners were unsuccessful in their motion for a class action. The nuisances identified in the Grand Jury's report consisted of *dust, noise, blasting* and *truck traffic* attributed to a substantial unlawful expansion of the quarry in 1986 without permits. The appellate court upheld the trial court's refusal to certify the class action for the group of homeowners residing within five square miles of the quarry, which sought non-economic and economic damages based upon allegations of "public nuisance for annoyance, inconvenience, and discomfort."

In denying the motion for class certification, the trial court stated "common questions of law or fact do not predominate," and that "special injury" involves another element where proof would vary significantly amongst the estimated 11,075 class members. The trial court's ruling was supported by two reports prepared on behalf of the quarry owner, both of which acknowledge that the noise and vibration experienced by each class member would vary considerably depending on a number of environmental and property-specific factors:

> "*…[T]he Salter report found that "[t]he variation in noise is due to the wide range of distances between the noise sources and homes and shielding of the noise provided by natural terrain, intervening homes and vegetation. Because of these factors, in many locations, neighbours within a few hundred feet of each other have dramatically different exposure." The report notes that noise exposure also varies inside of individual homes due to the orientation of rooms, nature of furnishings, size and construction of windows and whether windows are open or closed.*"
>
> "*The…report, prepared by Blast Dynamics, Inc., analyzed how blasting at the Quarry affected neighbouring residents. This report identified a*

[134] <https://cite.case.law/ohio-st/90/144/>.

[135] *Frieman v. San Rafael Rock Quarry, Inc.* 10 Cal.Pptr.3d 82 (2004) 116 Cal.App.4th 29, <https://casetext.com/case/frieman-v-san-rafael-rock-quarry-inc> accessed 10 April 2023.

> *number of variables in the way that different residents would experience vibration from blasting. These variables include the presence of rock or soil formations that alter the frequency of blast waves, the natural or "resonant" frequencies in each structure that changes the response to vibration, distance from the blast site and differences in the duration of the blasts. The report included a geologic map of the area showing a combination of soil, rock, sandstone, artificial fill, bay mud and marshland under the relevant area. The report noted that soil typically filters out high frequency energy, while rock transmits it. Test blasts were detonated at the Quarry and instruments were placed at various locations to evaluate the differing effects. The results of the velocity measurements showed a decrease in impact with distance from the blast site, but the frequency measurements showed no consistent pattern. The report concluded that: "[t]he test data shows that it is unreasonable to expect that any two sites will experience the same blast related vibration...."*

2.11 Quarry Noise Causes Infliction of Emotional Distress - Joint and Several Liability Imposed

In *Town of Stonington et al. v. Galilean Gospel Temple et al.* (1999),[136] the Supreme Judicial Court of Maine affirmed the trial court's award of $5,000 to the Eatons for *Negligent Infliction of Emotional Distress* (NIED) caused by the operation of the quarry. Notes of the court:

> *"[15]…[T]he Eatons state that the defendants' operation of the quarry "generated noise, dust and interfered with Plaintiffs' possession and use of their property and residence," and that the defendants' "cutting and burning ... deprived Plaintiffs of the safe and quite enjoyment of their home." By echoing language that describes the essence of a private nuisance complaint, the Eatons' complaint provided Cormier and the Temple fair notice of a claim that the operation of the quarry resulted in a nuisance."*
>
> *"[12] Competent evidence supports the court's finding that the Eatons suffered from serious emotional distress. Mr. Eaton testified that he suffered from throbbing headaches and depression. Mrs. Eaton testified that the noise has caused her neck muscles to tighten. As a result, she was given muscle relaxants and a collar. Given this testimony, the court did not err in finding that the Eatons suffered serious emotional distress. See* Gammon, 534 A.2d at 1283 *(holding that the evidence supported plaintiff's NIED claim where plaintiff had nightmares, his personality was affected and his relationship with his family deteriorated)."*

In *Manford F. Eaton et al. v. Francis A. Cormier et al.* (1999),[137] the trial court found Cormier and Galilean Gospel Temple jointly and severally responsible for a private nuisance and awarded $20,000 in damages to

[136] *Town of Stonington et al. v. Galilean Gospel Temple et al.*, 722 A.2d 1269 (1999) 1999 ME 2, <https://law.justia.com/cases/maine/supreme-court/1999/1999-me-2-0.html> accessed 10 April 2023.

[137] *Manford F. Eaton et al. v. Francis A. Cormier et al.*, 748 A.2d 1006 (2000) 2000 ME 65, <https://cite.case.law/a2d/748/1006/> accessed 10 April 2023.

Manford and Helen Eaton. The award was affirmed by the Supreme Judicial Court of Maine, with the following remarks:

> "*[2] This is the second time this case is before us. See generally* Town of Stonington v. Galilean Gospel Temple, 1999 ME 2, 722 A.2d 1269.[138] *We previously determined that the Eatons had properly pled a cause of action for nuisance against Cormier and the Temple and remanded for a trial on the issue, as well as for a determination of whether Cormier and the Temple should be held jointly and severally liable should a nuisance be found.*" *See id. at 13-16,* 722 A.2d at 1272-74.
>
> "*[3] Following our remand, the court conducted a hearing in which it took notice of evidence introduced in the prior proceeding and heard additional evidence regarding conditions on the Eatons' property since the prior proceeding. It also heard testimony from officials of the Town of Stonington regarding their monitoring of the noise levels generated by the quarry and testimony from Cormier's son who acts as foreman at the quarry. The court then issued its decision in which it found that the quarrying activities constituted a private nuisance…*"
>
> "*[7]…[A]s we noted in our last opinion in this case, a landowner is liable for a nuisance created by the activity of a third party on the land if (1) the possessor knows or has reason to know that the activity is being carried on and that it is causing or will involve an unreasonable risk of causing the nuisance, and (2) the possessor consents to the activity or fails to exercise reasonable care to prevent the nuisance.*" [citations omitted]

2.12 Concussions from Recurrent Blasting Caused Property Damage and Distress in Body and Discomfort, Annoyance, Fright and Shock, and Expert Evidence Ruled not Entitled to Preferential Treatment as to Facts

In *Alonso v. Hills et al.* (1950),[139] as a consequence of recurrent quarry blasting operations, the California appeal court upheld the trial court's damages award of $2,650, consisting of $1,650 for damage to and depreciation of the property, and $1,000 for the plaintiff's distress in body and discomfort, annoyance, fright and shock. According to the homeowner, the residence is located in Rockaway Beach, a community of 300 homes and 200 yards (183 metres) distant from the quarry. The evidence that there were 85 homes and the distance was 300 yards (274 metres) from the quarry had no bearing on the outcome of the case.

Blasting conducted at the quarry on November 2, 1946, February 3, 1947, and on many occasions before and after caused violent concussions in the nature of earthquake thereby injuring the plaintiff's real property and building, and disturbed the enjoyment of the dwelling by plaintiff and his family, shocked plaintiff's nerves and injured his health, and caused his children great fear. The February 3, 1947 quarry blast launched a 3-pound rock (flyrock) that destroyed a bench on the property near which one of the plaintiff's daughters was standing, causing the plaintiff to lose sleep

[138] Town of Stonington v. Galilean Gospel Temple, 1999 ME 2, 722 A.2d 1269. <https://caselaw.findlaw.com/me-supreme-judicial-court/1386037.html> accessed 10 April 2023.

[139] *Alonso v. Hills*, 95 Cal.App.2d 778 (1950) 214 P.2d 50, <https://casetext.com/case/alonso-v-hills> accessed 10 April 2023.

and fear for his security and that of his family. As noted by the appeal court:

> *"[2] The recurrent blasting in the operation of defendant's quarry, causing cumulative injury to plaintiff's property and interference with its enjoyment and requiring injunctive relief could conceivably be considered as one line of conduct in the character of a nuisance giving rise to one cause of action, without necessity of separate statement of separate blastings."*

On the issue of the relevance of expert evidence argued by the quarry owner, the appeal court ruled that expert testimony was not entitled to preference over testimony as to facts, and that inferential evidence can overcome direct evidence:

> *"…[R]egular scientific expert testimony is not entitled to preference over testimony as to facts; the relative weight must be decided by the trier of facts." (Rolland v. Porterfield, 183 Cal. 466,469 [191 P. 913].)*
>
> *"[8] The finding that on November 2, 1946 [before the blast], plaintiff's property was of the reasonable value of $5,000 finds competent support in plaintiff's testimony that he figures the valuation of his house at that time in the neighborhood of $5,500. (Isenberg v. Sherman, 212 Cal. 454, 483 [298 P. 1004, 299 P. 528], 10 Cal.Jur. 1023.) Appellant's attack on plaintiff's evidence on the ground of contradictions in his statements as to his cost price go to the weight of this evidence only, of which the trier of facts is the sole judge."*
>
> *"[9] It is true that there was no direct evidence as to structural weakening. However, plaintiff testified that after the November 2 blast there were cracks all through the exterior of the house, the stucco outside was buckled, the window sills and frames all knocked out of proportion, the plumbing leaking, barbecue pit and terrace ruined. From such evidence of visible injury an inference can be drawn that also the general structural strength of the building must have suffered. Whether the inference should be drawn in this case was again for the trier of facts. (Blank v. Coffin, 20 Cal. 2d 457, 461 [126 P.2d 868]; 10 Cal.Jur. 738,739.) Such inferential evidence can also overcome direct evidence to the contrary." "[I]t is elementary that direct evidence may be disbelieved and contrary circumstantial evidence relied upon to support a verdict or finding." (Gray v. Southern Pacific Co., 23 Cal. 2d 632,641 [145 P.2d 561].)*

2.13 Property Damage From Vibrations Caused by Repeated Blasting (Especially at Low Frequencies) an Absolute Certainty

Repeated blasting causes damage to structures, especially at low frequencies below 20 Hz (or 20 cycles per second). Amplification factors of four (4) are reported in BOM RI 8507.[140] Dr. Sam Kiger, a now-retired Civil and Environmental Engineering professor at the University of Missouri, presented, in part, the following in connection with expert evidence in

[140] US Bureau of Mines RI 8507, *"Structural Response and Damage Produced by Ground Vibration From Surface Mine Blasting,"* 1980.

Fontaina Scott v. Mountaineer Grading Co. – Putman Co. Civ. Act. No. 09-C-286:[141]

> *"At relatively low dominate frequencies that is below about 20 Hz (or 20 cycles per second), blast induced ground vibrations are amplified by structures….Amplification factors of 4 are reported in BOM RI 8507. Michael J. Mann of the Ohio Department of Natural Resources Division of Mines & Reclamation investigated the response of structures at larger distances from surface mining operations where lower ground vibration frequencies are much more likely to dominate (Mann, 2003).*[142] *The data published by Mann…indicate measured structural amplifications as high as 10….This is the most damaging type of ground vibrations because [of] amplification induced in…homes at these low frequencies."*
>
> *"Blast induced ground vibrations can be amplified by local soil and other geological conditions. For example in BOM 656*[143] *they report that the thickness of overburden, i.e. the thickness of the soil layer over bedrock, has a direct effect on amplitude and frequency of ground vibrations from blasting. They go on to indicate that the effect is to increase amplitude and lower frequencies. Note that both increased amplitude and lower frequencies will result in increased damage to structures. The Soil layer frequency, f, can be estimated from the textbook by Woods & Hall (1970)*[144] *as f = V / 4H, Hz; where V is the seismic velocity in the soil layer, H is the soil layer thickness, and the units of the frequency, Hz, is cycles per second. Whenever vibration frequencies generated by blasting operations match the soil layer frequencies, amplification will occur. The thickness of soil layers often vary significantly between hilly terrain and low lying valley terrain. Thus, unexpected local amplifications of the blast induced ground vibrations can occur resulting in peak ground motions being larger at relatively far away locations than they are at locations relatively close to the blasting."*
>
> *"All homes undergo daily and seasonal dimensional changes due to things like humidity variations and changing temperatures, like the sun moving from one side of the home to the other (the warm side will expand relative to the cooler side); or seasonal variations of temperature and humidity. For example most of us have experienced a "sticking door" or a door that will not close (or easily open) during certain times of the year. These environmental effects will cause strains in the walls,*

[141] "Scott owns property in Fraziers Bottom and says the defendant company's blasting operations on the new U.S. 35 in 2008 affected her and her property. She lists property damage, nuisance, trespass, negligence and/or gross negligences and strict liability in her complaint. She seeks compensatory and punitive damages, attorney fees, costs and other relief." <https://putnam112.rssing.com/chan-8516446/all_p14.html> accessed 10 April 2023.

[142] Mann, M.J. "Response of Manufactured Houses to Blast Vibrations," Ohio Department of Natural Resources, Division of Mines and Reclamation, New Philadelphia, Ohio, USA, 2003. <https://files.dep.state.pa.us/Mining/BureauOfMiningPrograms/BMPPortalFiles/Blasting_Research_Papers/State%20Reports/2003%20Mann%20-2003%20BAI%20modular%20Homes.pdf> accessed 10 April 2023.

[143] Bureau of Mines Bulletin 656, "*Blasting Vibrations and Their Effects on Structures*," 1971.

[144] Richart, F. E. Jr., Hall, J. R. Jr., and Woods, R. D., "*Vibrations of Soils and Foundations*," Prentice-Hall, 1970. <https://www.amazon.com/Vibrations-Foundations-Prentice-Hall-International-Theoretical/dp/0139417168> accessed 10 April 2023.

ceilings, structural framing, tile covered surfaces, and etc. These strains are known by engineers as prestrains, that is strains that exist before an event like a blast induced ground vibration. The prestrain condition may be such that a very small vibration will push the item, like a wall panel, a framing connection, or piece of tile, over its strain limit and result in a crack or loosening of a structural frame connection. Once a crack is initiated the crack will grow at a much lower level of vibrations than was required to initiate the crack. This is because of the stress concentration that exists at the crack tip; envision for example a small crack in an automobile windshield where even a small bump from ones hand can cause the crack to grow. Thus, even low levels of repeated occurrences of blast induced ground vibrations can cause significant damage to a home over time. For example the German vibration standard is 0.16 ips [4.06 mm/s] for buildings with visible damage and cracks in masonry. See for example Table 1 in "Vibration Criteria for Historic and Sensitive Buildings" by Konon and Schuring (1983)."[145]

"The fact that these prestrain conditions can produce a condition in the home such that damage to a home will occur at even very low levels of vibrations is acknowledged in BOM RI 8507[146] *in their Conclusion 7 on page 68…This conclusion, agreed to by the 4 experts that authored RI 8507, clearly states that "…there may be no absolute minimum vibration damage threshold…"; that is, when inevitable pre strain conditions are present in a home, any blast induced ground vibrations might cause damage to the home."*

"In Bureau of Mines RI 8507 they suggest a maximum allowable ground vibration peak particle velocity [PPV] of 0.5 inches per second (ips) [12.7 mm/s] at which there is a 0.5 per cent probability of damage. However, the standards in many countries are much lower; for example…regulatory agencies in Leicestershire County, UK have established the upper limit on allowable peak particle velocity (ppv) as 0.24 ips [6.1 mm/s]; [I]n Australia the common limit is 0.2 ips [5.1 mm/s] and it is 0.001 ips [0.025 mm/s] for historical buildings and monuments for frequencies less than 15 Hz. Note that frequencies less than 15 Hz are very likely in blast induced ground vibrations at large distances from the blasts. The Australian standard for historical buildings of 0.2 mm/sec (0.001 ips) implies that if a building is really important the allowable vibration to prevent damage is extremely low.[147] *Therefore, standards in reality represent an economic decision. Since at almost any vibration level some homes might be damaged, but for the mine to operate at an economic level, some probability of damage is*

[145] Konon and Schuring, "Vibration Criteria for Historic and Sensitive Older Buildings," ASCE Preprint 83-501; American Society of Civil Engineers (ASCE), Houston, Texas, October 17-19, 1983.

[146] US Bureau of Mines RI 8507, "*Structural Response and Damage Produced by Ground Vibration from Surface Mine Blasting*," 1980.

[147] See Table 2 in Pesch, R. and Robertson, A., "Drilling and Blasting for Underground Space," Wollongong, NSW, 3-4, September 2007, <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.500.4403&rep=rep1&type=pdf> accessed 10 April 2023.

tolerated. The level of 0.5 ips [12.7 mm/s] widely adopted in the US is far greater than the standards adopted in other countries."

"The size of the blast induced ground vibration waves shaking the homes is large in comparison to the footprint dimensions of a typical home. The length of the ground vibration wave train is the duration of the blast induced ground vibration shaking at the homes, typically about 3 to 4 sec, times the speed of the ground wave, typically about 800 ft per sec [244 m per sec]. Thus, for a typical blasting event with multiple individual explosions the ground vibration wave train is about 3,000 ft [914 metres] long. These ground vibrations at long distances, i.e. more than 1,000 ft [305 metres], have a dominate frequency of the ground vibration equal to about 8 or 10 Hz (cycles per sec); for a frequency of 10 Hz a single cycle of the ground shaking is 80 ft [24 metres] in length (one cycle is up down and back up) so that the leading edge of the home is picked up then pulled down while the back of the home is being picked up; this up and down of the front and then back of the house occurs repeatedly for the full 3 to 4 second duration of the ground vibration; in this example that would be about 30 to 40 complete cycles (10 cycles per second for 3 or 4 seconds). When these repeated distortions of the house match the natural frequency of the house, the motions will be amplified and damage to the house will be significantly increased."

"It is recognized that the probability of damage to a home is relatively small in any single blast. However, numerous opportunities for an unlikely occurrence, like damage to the home, will result in a very likely occurrence of damage. For example, if the probability of damage to the home, Pd, in any single blasting event is 0.05, or 5 per cent; then the probability of not being damaged, Pu, is 95 per cent. One can use the probability Law of Independent Events to calculate the probability of damage occurring at least once in 100 events. Thus, assuming the probability of damage is the same for each event, 0.05, then the probability of ***not*** *being damaged at least once in 100 events (explosions) is:*

Pu-100 = (0.95)100 = 0.006

and the probability of the home ***being*** *damaged in 100 explosions is 1 minus the probability that it is not damaged, thus:*

Pd-100 = 1 - 0.006 = 0.994

This implies that the probability of damage in 100 events is about 99 per cent and that implies damage to the home would be almost certain. Therefore, even though damage is unlikely for any single blasting event, some damage in the form of cracking of walls, ceiling, tile, concrete,...etc. becomes very likely with numerous repetitions of blast induced ground vibrations. And once damage occurs (like cracking, nails pops, or framing joints loosening) that damage will increase at even lower levels of vibrations with repeated exposure to the vibrations."

"The quarry application states that blasting will occur at least twice a month, which means that there is a 99 per cent probability of damage to the more than 100 homes within about the first four years of quarry operations (about 8 years if blasting occurs only 6 out of 12 months per year)."

And, according to Sayed-Ahmed & Naji (2006),[148] ground vibrations can have a damaging effect on residential buildings, as occurred in the two case studies undertaken and presented at the 2006 International Structural Specialty Conference held in Calgary, Alberta:

> *"Subsurface construction blasting generates ground vibration which may have a damaging effect on residential buildings. Codes of practice define damage criteria to limit the effect of the vibrations resulting from the subsurface blasting on nearby structures. All these criteria are based on the soil Peak Particle Velocity (PPV) generated due to blasting on the ground surface close to the structure. The real culprit, however, is not the ground PPV but it is the structural response to the ground vibration. In this paper, the currently adopted safe limit criteria of ground vibrations generated by subsurface construction blasting are presented. Two case studies have been performed on two residential houses located nearby an excavation-by-blasting construction site [ST-051-1]…"*
>
> *"When a charge is detonated in a solid medium (like rock), a family of waves is generated. These waves generate different particle movement and travel at different wave velocities. The resulting ground-borne vibrations may have an effect on residential buildings ranging from disturbing the occupants to causing severe threshold "cosmetic" or structural damage. Problems may occur as a result of large amplitude (low frequency) vibrations, repeated occurrence of smaller amplitude vibrations, or from differential settlement induced by soil particles rearrangement [ST-051-1]."*
>
> *"Two case studies have been performed and discussed for two residential houses (one and two storeys) located adjacent to an excavation where blasting was to be used for excavating the rock. Analysis of the accumulated data recorded during blasting is presented and compared to the currently adopted ground vibration safe limit criteria. The PPV and the vibration frequency due to excavation by blasting measured close to these houses satisfied the existing safe limits criteria for subsurface blasting ground vibration. Despite this fact, both houses suffered threshold cracks and one of them even had structural cracks [ST-051-2]…"*

In another study of damaged residences beyond 300 metres from a Ugandan quarry undertaken by Yomekpe-Agbeno & Affam (2008),[149] the authors conclude that *frequencies* and *weather conditions* are important considerations when assessing damage potential of a particular blast, as are other factors related to type and quality of construction of structures and residences, and distance from the blast site.

Since 2003, when blasting activities started at the Plant North Pit quarry, residents living close to the pit have complained of cracks and

[148] Sayed-Ahmed, E.Y. and Naji, K., "Residential Houses Cracking Due to Nearby Construction Blasting: Critical Review of Current Safe Limits," 1st International Structural Specialty Conference, Calgary, Alberta, May 2006, <https://www.researchgate.net/publication/280530625_Residential_Houses_Cracking_Due_to_Nearby_Subsurface_Construction_Blasting_Critical_Review_of_Current_Safe_Limits> accessed 10 April 2023.

[149] Yomekpe-Agbeno, S. K. and Affam, M., "Establishing Ground Vibration Threshold Level for Open Pit Mining Environment – A Case Study," (2009) 10 Ghana Mining Journal 19-24, < https://doi.org/10.4314/gm.v10i1.42804>

general deterioration of their buildings, damages to electrical and electronic appliances and general nuisance by way of fright and noise, In October 2005, the Environmental Protection Agency ordered the temporary suspension of blasting operations at the Plant North Pit quarry:

> *"Damage caused to the building structures…cannot be attributed to a single cause alone. There are several causative agents such as; poor building materials quality, poor, foundation problems, differential settlement, ground vibration, ageing and building maintenance culture. The ground vibrations from the extensive open pit blasting activities can however, worsen the already precarious conditions of the buildings or they can act as catalysts to worsen the already deplorable state of the structures [p. 19]."*
>
> *"A total of 542 blasts were recorded and out of this only 20 blasts (representing about 6% of total blasts) had ground vibration levels above 1.5 mm/s while 9 blasts had blast values in excess of 120 dB(L) which is the recommended Environmental Protection Agency (EPA) of Ghana levels. The records also show that attention was not paid to Frequencies (at vibration levels were recorded) and weather conditions at the times of the monitoring exercises. Frequencies and weather conditions are important parameters when assessing the damage potential of a particular blast in terms of ground vibration and air blast. According to Konya and Walters (1990), frequency is an important factor in assessing the damage potential of vibrations as structural resonance lies in the low frequency range typically of 5 to 20 Hz and blast vibration in this frequency range can cause a resonance response in structures which produces increased displacement and strain, giving serious problems in the structures. Also air blast levels rise with increased overcast skies with a corresponding increased damage potential [p. 22]."*

Considering the substandard quality of the buildings in the Prestea Township, the authors of the study conclude that the German Standard of 8 mm/s Peak Particle Velocity (PPV) is too high, and recommend that the maximum ground vibration not exceed 2 mm/s:[150]

> *"Even though this level [2 mm/s] can increase drilling and blasting costs considerably, it is considered a better option than expensive lawsuits in the likely event of any further damages that may be caused to building structures in the township [p. 19]."*

2.14 Insurance Company Denies Damage Claim Caused by Vibrations from Quarry Blasting

In *Hernandez v. Citizens Prop.* (2020),[151] the Florida appellate court held that insurance coverage is excluded for cracks in walls and floors that occurred due to vibrations from off-site quarry blasting operations by a

[150] In *Seismograph Service Corporation v. Buchanan*, Okla., 316 P.2d 185, 187, [1957], the Oklahoma Supreme Court ruled that the "defendant cannot be aided by the substandard construction of the building if in fact the explosion caused the damage resulting in the substantial loss of value for which damages are claimed."

[151] *Hernandez v. Citizens Prop.*, 308 So. 3d 102 – Fla. Dist. Court of Appeals, 3rd Dist. 2020, <https://www.lexology.com/library/detail.aspx?g=7a837bcd-6ebb-46b3-97d3-42fac4688214> accessed 10 April 2023.

policy's earth-movement/settlement exclusion. Following is the observation of the court:

> *"The insured filed a claim for cracks in the walls and flooring of his house. The insured's engineer concluded that the damage was the result of soil underneath the house shifting from vibrations caused by blasting explosions at a nearby rock quarry. The insurer denied coverage, asserting an earth-movement/settlement exclusion of the policy. The insured filed suit and argued that the exclusion did not apply. The insured noted that the policy lists nine causes of loss that are considered "earth movement," and that the alleged cause of loss, blasting, is not included. The insurer moved for summary judgment, which the trial court granted, finding that the policy did not cover indirect damage to property as a result of earth movement that may have been triggered by off-site explosions. The appellate court affirmed. The earth-movement exclusion of the policy excluded coverage for damage caused by earth movement "unless direct loss by explosion ensues." The appellate court found that the earth movement at the property did not cause an explosion, but rather that the earth movement was caused by explosion."*
>
> *"The appellate court noted that the exclusion contains anti-concurrent causation language that "loss caused directly or indirectly" by certain causes is excluded "regardless of any other cause or event contributing concurrently" to the loss. It held that the policy's terms excluding "earth sinking, rising, or shifting," "settling, cracking, or expansion of the foundation," "whether caused by natural or manmade activities," unambiguously precluded coverage under the policy."*[152]

2.15 Diminution in Property Value and Loss of Property Use Occasioned by Blasting

In *Clay v. Missouri Highway Transp. Com'n* (MHTC) et al. (Rieke), (1987),[153] the Missouri Court of Appeal awarded the Clays $19,640 as the diminution in property value caused by blasting of rock either against MHTC or Rieke, the contractor, and $2,700 for the loss of use against Rieke only.

The Clays' residence sits above an aquifer, and the aquifer had supplied a well on their property with unusually high-quality drinking water since 1945. In November 1989, MHTC retained Rieke to cut a roadway for a new highway. Rieke used explosives to break up and remove rock from the roadway site, and caused damage to the Clays' property, which is 0.85 miles (1,368 metres) from the blasting site. Court observations were:

> *"Rieke tried to blast in a controlled fashion. Specially-placed explosive charges cut the rock and left smooth walls of rock for the sides of the*

[152] Lenzen, D. R., "Florida Appellate Court Holds Earth-Movement Exclusion Excludes Coverage for Cracking Damage Caused by Off-Site Blasting Vibrations," Phelps Dunbar LLP, August 25, 2020, <https://www.lexology.com/library/detail.aspx?g=7a837bcd-6ebb-46b3-97d3-42fac4688214> accessed 10 April 2023.

[153] *Clay v. Missouri Highway and Transp. Com'n*, 951 S.W.2d 617 (1987), Mo: Court of Appeals, Western District, <https://law.justia.com/cases/missouri/court-of-appeals/1997/wd51894-2.html> accessed 10 April 2023..

> *highway. At trial, some experts testified that this controlled blasting only caused shock waves to move about twenty feet [6.1 metres] into the rock. The Clays alleged, however, that the blasting caused vibrations at their home some .85 miles [1,368 metres] away and that it affected the quality and quantity of the water coming from the aquifer. More specifically, they alleged that due to cracks in the aquifer caused by the blasting, sediment such as sand and oil contaminated the aquifer and, ultimately, their well-water, that the water level of their well dropped, and that the water flow in their well was drastically reduced."*
>
> *"…[T]here was evidence to support the submission that vibrations or concussions resulting from the explosion entered the plaintiffs' property, for there was testimony that the Clays and their neighbours felt and heard the blasting. They also testified that they began to have problems with their water supply after the blasting. Thus, they do claim a trespass, and they do claim their damage resulted from the blast. What they do not claim, however, is that the vibrations or concussions which they felt directly caused their damage. Rather, they claim that the same blasting that caused the vibrations also, but separately, split and cracked rock outside their property, and that as a result, it caused a lowering of the water level in the entire aquifer, including that on their property, and polluted the aquifer that supplied their well."*

The Clays were not required to prove that the vibrations and/or concussions were the direct cause of the damage to their property, but only that blasting caused the damage. The following is worth noting:

> *"…[T]he trial court properly refused to require the Clays to prove that it was the vibrations or concussions from the blasting that directly caused their damage; they were required to submit only that it was the blasting that caused their damage. We so rule because we conclude from a review of the history of the doctrine of strict liability for blasting that, while such a claim may be established by proof of vibration and concussion, see Wiley v. Pittsburg & Midway Coal. Mining Co., 729 S.W.2d 228, 232 (Mo.App.1987), it may also be established by other methods of proof."*

As a matter of public policy, innocent parties whose properties have been damaged should not bear the costs of blasting by either the state or an industry, as noted below: :

> *"Policy considerations support such imposition of strict liability for blasting even though no physical invasion of the premises has taken place. Neither an industry nor the State should be allowed to use its property in an abnormally dangerous way that injures the property of its neighbours with impunity, because to do so is effectively an appropriation of the neighbour's property for the industry or State's use. The blaster, and not the wholly innocent party, should assume the costs of its blasting. See Atlas Chem. Indus., 514 S.W.2d at 316 (characterizing the damage inflicted on other people's property as inverse condemnation); Branch, 657 P.2d at 275."*
>
> *"…[T]hese principles have application here, where the Clays similarly claim that the blasting caused physical damage to their property by damaging the rock formations underlying nearby property, thereby causing injury to the aquifer or to other subterranean aspects of the*

> *property in question. They presented expert testimony by Dr. Paul Hilpman, a Professor Emeritus of Geology at the University of Missouri and the Director of the Centre for Underground Studies, to support this theory. He testified that the blasting damaged geological structures that resulted in the contamination of the Clays' well. Dr. Hilpman testified that the blasting fractured rock and sandstone layers in the aquifer and that these fractures in turn caused the water table to drop and allowed oil to migrate up into the water-producing area of the rock strata. This resulted in a lower water level in the Clays' well and in pollution of their well water. This type of damage is equally serious and equally likely to affect the value of property as is damage caused by vibrations or concussions on the property. We find the Clays' proof of damage was sufficient to support their strict liability for blasting and inverse condemnation claims."*
>
> *"Dr. Hilpman testified that some of the rock had to be blasted and that the blasting would cause more subterranean fracturing than simple cutting. He also testified that the oil showed up in the Clays' well because it was able to migrate up into the water zone through fractures in a limestone layer that were caused by blasting."*

In *Davis v. L & W Construction Company*, (1970),[154] *air concussions* and ground *vibrations* from blasting at a quarry about six-eighths of a mile (1,207 metres) away damaged the Davis residence. Their two-storey residence, stucco covered and hollow tile structure with basement, measuring 32′ × 32′, was in "good solid condition prior to the blasting" by the quarry operator.

When quarrying operations were in progress, which had worsened by 1966, the Davis' house shock, a window broke, and structural cracks began to appear. An experienced building contractor testified on behalf of the homeowners, stating that one time while in the home the building was in good condition and that during a second visit he found cracks, "both diagonal and vertical." He concluded,

> *"[V]ertical or horizontal cracks cannot result from settling and are usually caused by jar, shaking or possibly wind."*

Neighbours Albert Poli and John Head also testified as to the damages each sustained to their home as a consequence of the blasting quarry operations.

- *Albert Poli stated he lives about three-fourths mile [1,207 metres] west of the quarry, in a 24′ × 48′ frame house with cement block basement. The structure had never settled, but the foundation is shaken and cracking all over.*
- *John Head testified he resides approximately 70 rods [352 metres] southeast of plaintiffs [Davises], or about one and a fourth miles [2,012 metres] from the quarry. He had seen cracking and hairline cracks in the Davis home. His more remote residence trembled*

[154] *Davis v. L & W Construction Company*, 176 NW 2d 223(1970) Iowa Supreme Court, <https://www.casemine.com/judgement/us/5914c7a3add7b049347e4377> accessed 10 April 2023.

> *whenever there was blasting at defendant's quarry, and every room reveals damage to plaster and paper.*

The Iowa Supreme Court ruled in favour of the Davises and awarded damages, measured as the loss in market value, based on a before- and after-blasting analysis, while holding the quarry operator "liable without fault" for engaging in a notoriously hazardous activity, as noted below:.

> "*Surely it is a matter of common knowledge, and we accord judicial notice to the fact, that blasting by use of dynamite or other explosives is a hazardous activity and as such likely to damage others. See Boyce v. United States, D.C., 93 F. Supp. 866, 868;*[155] *31 C.J.S. Evidence § 9, page* *226 *824; and 29 Am.Jur.2d, Evidence, section 23, page 60.*
>
> *Since 1916 we have consistently adhered to that concept sometimes previously referred to as strict liability, but in cases of the nature here involved, now more appropriately termed "liability without fault".*" [citations omitted]
>
> "*…[I]f one engages in an activity on his own land of such hazardous nature as to involve risk of harm to the person, land or chattels of neighbouring parties, he is liable for the consequences proximately resulting therefrom without regard to degree of care, scientific manner in which done, purpose or motive.*" [citations omitted]
>
> "*And, as stated in Monroe v. Razor Construction Co., supra*[156]*, loc. cit., 252 Iowa 1252, 110 N.W.2d 252*[157]*: "Under this rule, negligence of the defendant need not be shown as an essential element of plaintiffs' recovery.*" See also Cronk v. Iowa Power & Light Co., 258 Iowa 603, 613, 138 N.W.2d 843[158].
>
> "*Consequently the user of explosives acts at his own peril and is liable if damage proximately results to another, either from the direct impact of debris thrown by the blasting, or from consequential concussions or vibrations. In addition to authorities cited, supra, see Exner v. Sherman Power Const. Co., (2 Cir.) 54 F.2d 510, 512-513;*[159] *Garden of the Gods Village v. Hellman, 133 Colo. 286, 294 P.2d 597, 600-601;*[160] *Morse v. Hendry Corporation, Fla. App., 200 So.2d 816, 817;* [161] *Berg v. Reaction Motors Div., 37 N.J. 396, 181 A.2d 487, 492-494;*[162] *Davis v. Georgia-Pacific Corporation, supra, loc. cit., 445 P.2d 483; Bedell v. Goulter, 199 Or. 344, 261 P.2d 842, 845-846;*[163] *and Annos. 20 A.L.R.2d 1372, 1377*[164]*.*

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155 *Boyce et al. v. United States*, *Huiskamp et al. v. United States*, *Wells v. United States*, *Campbell et al. v. United* States, 93 F.Supp. 866 (1950), <https://law.justia.com/cases/federal/district-courts/FSupp/93/866/1971773/> accessed 11 April 2023.

156 *Monroe v. Razor Construction Company*, 110 NW 2d 250 (1961), Iowa Supreme Court,

157 *Monroe v. Razor Construction Company*, 110 NW 2d 250 (1961), Iowa Supreme Court,

158 *Cronk v. Iowa Power and Light Company*, 138 N.W. 2d 843 (1965), Iowa Supreme Court, <https://law.justia.com/cases/iowa/supreme-court/1965/51567-0.html> accessed 11 April 2023.

159 <https://law.justia.com/cases/federal/appellate-courts/F2/54/510/1498099/>

160 <https://casetext.com/case/garden-of-the-gods-village-v-hellman>

161 <https://casetext.com/case/morse-v-hendry-corporation>

162 <https://law.justia.com/cases/new-jersey/supreme-court/1962/37-n-j-396-0.html>

163 <https://casetext.com/case/bedell-et-ux-v-goulter-et-al>

164 <https://revistas.pucp.edu.pe/index.php/iusetveritas/article/download/15319/15780>

2.16 Vibration Damage Awards Caused by Blasting Restricted to Five-Year Limitation Period

In *Harrod Concrete and Stone Co. v. Melton III, et al.*, (2007),[165] eight homeowners and one tenant (Appellants) had their respective damage awards set aside by the appellate court of Kentucky and remanded to the lower court for further proceedings, consistent with a five-year limitation period successfully argued by Harrod (the quarry owner), restricting the computation of proven damages subsequent to August 1996. The failure to timely file the claims for damages caused by vibrations from blasting reduced the amount of damages to which each homeowner (and one tenant) should have been entitled, had the claims been filed in the early 1980s rather than in August 2001. Following observations were important:

> *"The homes allegedly all had varying degrees of damage, including cracks in the interior and exterior walls and slabs, cracks in chimneys and joints, bowed walls, cracked drywall, nail pops, and fogged and/or cracked windows. All of the homes are located in Franklin County, Kentucky over an area of roughly two square miles."*
>
> *"…[The damage here was known and present as far back as the early 1980's for some of the Appellees. We agree with Harrod that "[c]racks are not latent or inherently undetectable. Neither are nail pops, drywall cracks or cracked and fogged windows. These conditions are patently obvious." Certainly, all the Appellees had knowledge of the blasting vibrations occurring as a result of Harrod's limestone operation from the first day of moving into their respective homes. Additionally, Harrod introduced evidence at trial showing that many Appellees knew or should have known of the damages and the possible cause before August 1996. For example, the Dunns and Devers filed insurance claims for blast damage and received payments before 1996. Moreover, the Olivers filed insurance claims before 1996, which were denied; however, they had been advised in June 1996 by an engineering firm that they had blast damage. Nor are we persuaded that Appellees were unable to determine the cause of the damage because they allegedly complained to state mining officials and to Harrod directly about the alleged blast damage and were told that the blasting was not causing their property damage. The Appellees [homeowners and one tenant] are not relieved of their responsibility to exercise reasonable diligence to discover the cause of their damages merely because Harrod may have denied responsibility. Thus, the trial court erred and its instructions to the jury should have limited the award, if any, to only those damages proven to have occurred subsequent to August 1996. Accordingly, we reverse and remand."*

The property damage attributed to vibrations from repeated blasting at the quarry was supported by the evidence of the Appellees' expert, Dr. Deatherage, whose qualifications were unsuccessfully challenged by Harrod. Important observations include:

[165] *Harrod Concrete and Stone Co. v. Melton III, et al.* Ky: Court of Appeals 2007, <https://law.justia.com/cases/kentucky/court-of-appeals/2007/2005-ca-001712.html> accessed 11 April 2023.

> *"Dr. Deatherage testified that he is a professor of civil engineering with a Ph.D. in civil engineering. Moreover, he has numerous peer reviewed publications which he has authored. Dr. Deatherage's education, training, and experience were sufficient to qualify him as an expert. To the extent that Harrod argues Dr. Deatherage's opinions fall outside the scope of scientific, technical or other specialized knowledge pursuant to Daubert, we disagree."*
>
> *"The principles established in Daubert and its progeny concerning the admissibility of expert testimony "apply not only to expert testimony based on scientific knowledge, but are equally applicable to expert testimony based on technical or other specialized knowledge."*
>
> *"…[I]n forming his opinions, Dr. Deatherage visually inspected the homes and interviewed the occupants. Dr. Deatherage also reviewed countless photographs of the alleged damage, reviewed the opinions of Harrod's experts, as well as reviewed technical publications regarding blast vibrations."*

2.17 Quarry Permit Denial Supported by Substantial Evidence of Land Use Incompatibility

In *Vulcan Materials Co. v Guilford County Board of Cty.com'Rs* (1994),[166] the Board denied Vulcan's application for a quarry comprising approximately 235 acres, with an initial 10-acre quarry pit 300 feet (91.44 metres) deep, and eventual expansion to 17 to 20 acres. Vulcan's appeal resulted in the reversal of the Board's decision by the Superior Court, which then led to a further appeal by the Board to the North Carolina Appeals Court, which restored the Board's decision to deny the quarry permit.

Those opposed to the issuance of the quarry permit offered competent and material evidence as follows in summary form:

- there are 119 homes within 3,000 feet [914 metres], and 450 homes within one mile [1,609 metres], of the quarry site;
- Mt. Hope Church Road, a two lane paved road, is traveled twice a day by ten school buses;
- the area immediately surrounding the quarry site is residential and agricultural, although a commercial business, Replacements Ltd., has a 100,000 square foot facility some 11,000 feet [2.08 miles] from the proposed quarry site;
- area residents obtain their water from wells which are generally 80 [feet] [24.4 metres] to 140 feet [42.7 metres] deep;
- the proposed quarry site is located in part of a watershed for a planned drinking water source;
- one area resident testified that when she put her home, which is located directly across from the site, up for sale and disclosed that a quarry was proposed for the site, no one even looked at the house;

[166] *Vulcan Materials Co. v Guilford County Board of Cty.Com'Rs,* 444 S.E.2d 639 (1994) 115 N.C. App. 319, <https://law.justia.com/cases/north-carolina/court-of-appeals/1994/9318sc750-1.html> accessed 12 April 2023.

- the Guilford County Comprehensive Plan adopted in 1986 reserves the area of the site for residential use;
- neighbours of a Vulcan quarry in Elkin, North Carolina, stated through affidavits that they have suffered broken windows, cracked walls, dried up wells, dust, noise and falling rocks as a result of the operation of that quarry;
- Vulcan was fined $10,000 by the United States Department of Labour for an incident in which a man was killed by flying debris [flyrock] from a quarry blast while mowing his lawn some 900 feet [274 metres] from a Vulcan quarry in Weston, Illinois; and
- there are several quarries already operating in Guilford County; and, according to the National Environmental Journal, Vulcan is the seventh worst emitter of toxic chemicals in the United States, based on air, water, land, underground, public sewage, and off-site releases.

The Carolina appeal court rejected Vulcan's argument that because "quarrying" is a permitted use within the context of the zoning ordinance, it necessarily is in "harmony with the area." As concluded by the Carolina appeal court, the proposed quarry is not in harmony with the character of the area:

> *"…[C]ompetent, material, and substantial evidence reveals that the use contemplated is not in fact in "harmony with the area in which it is to be located" the Board may so find. See 3 Robert M. Anderson, American Law of Zoning § 21.13, at 682 (3d ed. 1986); 3 Rathkopf § 41.13, at 41-83; see Triple E. Assocs. v. Town of Matthews, 105 N.C. App. 354, 358, 413 S.E.2d 305, 307-08, disc. rev. denied 332 N.C. 150, 419 S.E.2d 578 (1992); Piney Mountain Neighbourhood Assoc., Inc. v. Town of Chapel Hill, 63 N.C. App. 244, 251, 304 S.E.2d 251, 255 (1983); People's Counsel for Baltimore County v. Mangione, 85 Md. App. 738, 584 A.2d 1318, 1322-23 (1991)."*

2.18 Council Ignores Complaints of Damage Attributed to Quarry Blasting – A "Civil Matter"

Residents in the communities surrounding Roadstone's Belgard quarry complaining of damages to their houses from blasting operations were advised by South Dublin County Council in March 2021 that their only remedy was to pursue costly and time-consuming civil actions against the owner of the quarry (O'Flaherty, 2021).[167]South Dublin County Council has advised that alleged damage to residential properties from the operation of commercial activities "are a civil matter", when asked about alleged damage to houses near Roadstone's Belgard quarry. As previously reported in The Echo, a resident near the quarry claimed that the routine

[167] O'Flaherty, A.., "Alleged damage to property from blasting is a 'civil' matter,'" Echo.ie, March 29, 2021. <https://www.echo.ie/alleged-damage-to-property-from-blasting-is-a-civil-matter/> accessed 12 April 2023.

blasting that is carried out has worsened in recent months, causing the windows and mirrors in his house to shake.

> When the story went online, a number of commenters claimed that reverberations from the quarry blasts, which occur on Friday afternoons, could be felt further afield in Hazelgrove, Citywest, Kingswood, Brookview, Fettercairn and Ard Mor. The issue was raised at Monday's monthly meeting of the Tallaght Area Committee, when Fianna Fáil councillor Charlie O'Connor asked the council's CEO if he was "dealing with complaints from local residents claiming alleged damage to their homes from constant blasting at the Roadstone Quarry." The council advised that, "damage to residential properties from the operation of commercial activities are a civil matter"….
>
> …Brownsbarn resident Michael Fogarty claims that the blasting at the site started occurring twice a week for several months last year, and the level of disruption to nearby residents has increased.[168] Mr Fogarty, who has lived in the area for 14 years, told The Echo: "When we first moved here there was always an explosion on a Friday – you got used to it".
>
> "But a few months ago, they started doing them on Tuesdays as well. Having explosions once a week was horrible, but twice a week is a disaster. I was at home on a Tuesday before Christmas and the mirror fell off the fireplace, the windows shook and my four-year-old started bawling crying. The houses were shaking. Some of the explosions aren't bad, but some of them are really, really bad."

2.19 St Marys' (Votorantim Cimentos) Blasting Quarry Continues to Generate Complaints

A sampling of homeowner complaints and environmental damage attributed to Votorantim Cimentos' Bowmanville, Ontario, blasting quarry and cement plant are summarized as follows:

- "Higher incidence of blasting concerns in past month and a half [Jan–Feb 2021]." "Vibrations have been within [regulatory] limits, but…the blasts are being felt and disturbing the community members." Complaint referenced where frame fell of[f] a wall." "Strong odour experienced during some blasts… There have been comments about odours at the time of the blasts before. In the 1st quarter of 2020, there were four complaints about blasting; in the 2nd quarter 2020, there were three noise complaints; in the 3rd quarter 2020, there were 18 noise complaints, 4 dust complaints and 1 odour complaint; and in the 4th quarter of 2020, there were two noise complaints. (February 23, 2021 Community Relations Committee Meeting Minutes)

[168] <https://www.echo.ie/residents-claim-explosions-at-belgard-quarry-have-worsened/>

- "Many complaints are related to blasting and come from outside the immediate surrounding area." (September 11, 2018 Community Relations Committee Minutes).
- Received eight complaints (vibration, noise and dust) in third-quarter of 2017 (to October 4). (October 3, 2017 Community Relations Committee Minutes)
- Received four complaints (noise, flooding and odour) in the second quarter 2017, and St. Marys refused to discuss shoreline erosion (Cedar Crest Beach) with community members on advice of legal counsel due to legal proceedings, an issue that had been raised at previous community meetings. "Community believes that St. Marys should not be able to decline a new member to the committee, and that discussion should be allowed to continue even if the member chosen was involved in legal action against St. Marys." "Complaints reported to MNRF/MOECC etc can't be reviewed with the complainant unless he/she authorizes the MNRF/MOECC." (June 6, 2017 Community Relations Committee Minutes)
- Received 26 complaints (blasting, plume, noise and dust) in 2016 (November 29, 2016 Community Relations Committee Minutes)
- "St. Marys Cement reported exceedances in air emissions on five occasions in 2015 (Swinson, 2016).[169] "According to St. Marys "it is not abnormal to have exceedances." "St. Marys' operations released 4,096 tonnes of sulphur dioxide between January 1 and December 31, 2015," whereas, "[t]he Ministry of Environment and Climate Change allows for 3,511 tonnes."[170]
- "Clarington council…heard there were 13 community complaints in 2015."
- In 2014, St. Marys' Bowmanville operation was the 10th largest emitter with 7,135 tonnes (combined emissions for a group of contaminants known as "criteria air contaminants" that cause air-quality-related issues such as smog and acid rain). These contaminants include sulphur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide and ammonia.[171]
- Received "a large number of complaints about blasting during the 2010 winter [Christmas] holidays (Hatherly, 2011)."[172]
- Accelerated erosion rates along the Port Darlington shores (Cedar Crest Beach), primarily in the area bounded by 37 and

[169] Swinson, S., "St. Marys Cement reports several exceedances in air emissions in 2015," *toronto.com*, June 15, 2016, <https://www.toronto.com/news-story/6722518-st-marys-cement-reports-several-exceedances-in-air-emissions-in-2015/> accessed 12 April 2023.

[170] Ibid.

[171] Ministry of the Environment and Climate Change, Chapter 3, Section 3.05, p. 337, <https://www.auditor.on.ca/en/content/annualreports/arreports/en16/v1_305en16.pdf> accessed 12 April 2023.

[172] Hatherly, T., "St. Marys Cement to stop blasting during winter holidays this year," DurhamRegion.com, August 3, 2011, <https://www.durhamregion.com/news-story/3452188-st-marys-cement-to-stop-blasting-during-winter-holidays-this-year/> accessed 12 April 2023.

> 155 Cedar Crest Road, have been clearly identified in reports and substantiated by property owners through years of historical photos and documentation to have started following the original construction of St Marys Cement Pier in the 1970s [which protrudes 650 metres out from the shore]. It has been clearly seen, despite empirical models that the pier has modified the natural beach dynamics in the area and cut off the movement of sand along the north shore which is necessary for the maintenance and preservation of the beach. (Municipality of Clarington, Report EGD-015-17, p. 14)

A vast number of complaints lodged over a number of years by neighbouring homeowners at a considerable distance from the 556-acre Bowmanville quarry are related to blasting, even though St Marys has an agreement with the nearby OPG Darlington Nuclear Generating Station, about 5 kilometres away, to ensure that St Marys' blasting "do[es] not result in ground movement [vibration] greater than three millimetres per second [3 mm/sec] [para. 66]."[173] It is unknown as to where the seismograph(s) are positioned to measure the ground vibrations from blasting at the quarry.

The closest residence is 250 metres from the quarry, which operates between 10 and 20 hours each day (Scales, 2017).[174] Somehow, to the detriment of the health and safety of the community, St Marys Cement's predecessor (Blue Circle Canada Inc.) was able to convince the Municipality of Clarington to exempt the operations from enforcement of Municipal Noise By-law 2017-071, as amended.[175] It is doubtful that anyone residing in the subdivisions surrounding the quarry and cement plant operation is even aware of the noise exemption. The municipal noise by-law is far more restrictive than MECP noise guideline NPC-300 or NPC-119 (blasting). Now, the only effective remedy available to residents living in proximity to the quarry and cement plant and who continue to be subjected to intolerable noise levels (e.g., blasting, equipment, etc.) on an ongoing basis is to initiate a civil action against St Marys Cement (Votorantim Cimentos) for *nuisance* and *trespass.* All *adverse effects*, including noise, airblast, vibrations, dust, toxic fumes and flyrock, are not permitted to leave the licensed site.

> "*The Municipality of Clarington confirmed that in accordance with section 2.2(e) of Noise By-law 2017-071, St. Marys Cement (referred to in the By-law by its former name, Blue Circle Canada Inc.), its licenced pit and quarry operations and all related accessory uses are granted an*

[173] Record of Proceedings, Including Reasons for Decision, Dec 3 to Dec 6, 2012, Application to Renew Power Reactor Operating Licence. <http://nuclearsafety.gc.ca/eng/the-commission/pdf/2012-12-03-Decision-DarlingtonEA-e-Edocs4105509-final.pdf> accessed 12 April 2023.

[174] Scales, M., "St Marys Cement builds lasting legacy," Canadian Mining Journal, April 1, 2017. <https://www.canadianminingjournal.com/featured-article/st-marys-cement-builds-lasting-legacy/> accessed 12 April 2023.

[175] Office Consolidation of By-law 2007-071, as amended. <https://weblink.clarington.net/WebLink/DocView.aspx?dbid=0&id=58848&page=1&cr=1> accessed 12 April 2023.

> *exemption from the noise restrictions that the by-law puts into place. This exemption applies to the entirety of the site. Further, the noise curfew provisions of the by-law are not applicable to these activities at the site."*[176]

At the Sept 11, 2018 Community Relations Committee meeting[177] Votorantim Cimentos (St Marys/CBM) blasting quarry complaints were raised, to which Votorantim Cimentos simply responded as follows without taking any corrective measures:

> *"…[N]ot much can be done to muffle the noise from twice weekly blasts that takes place at the limestone quarry [a continuing nuisance that residents in neighbouring subdivisions will have to endure for 65 more years from 2022 to 2087.]…"*[178]

At two blasts a week, assuming 50 weeks in a year, and a quarry life expectancy of 65 years as of 2022, means that three more generations of homeowners in the neighbouring subdivisions will be subjected to the adverse effects of 6,500 blasts at Votorantim Cimentos (St Marys/CBM) quarry operations. Assuming an average of 50 blastholes per blast, three generations of homeowners will be exposed to the adverse and cumulative effects of 325,000 explosions.

Clairington Noise By-law 2007-071, as amended, from which St Marys Cement (Votorantim Cimentos) has been exempted to the detriment of homeowners in the neighbouring subdivisions, has a number of provisions, including one that does not permit disturbing noises to be heard beyond the property:

> *(g) any noise which may be heard beyond the lot upon which it is made at sufficient volume to disturb persons beyond such lot;*

2.20 On-going Complaints of Damage Attributed to Blasting at Vulcan's Quarry (Lorton, VA)

Residents within a mile or two [3.22 kilometres] of the Vulcan quarry in Lorton, Virginia, have been complaining for years about the adverse impacts caused by blasting quarry operations.[179] From the edge of the quarry, there is a separation of 320 feet (97.5 metres) to the closest homes in Occoquan Overlook and 180 feet (54.9 metres) in SouthPointe, Lorton, Virginia.

> *"For years, residents within a mile or two of the Vulcan quarry in Lorton have heard the twice-weekly thuds of explosions, watched vases bounce across tables and pictures rattle on walls…."*

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[176] St Marys Cement Community Relations Committee, September 29, 2020. <https://www.stmaryscement.com/Documents/Bowmanville%20CRC/2020%20September%2029th%20CRC%20Minutes.pdf> accessed 12 April 2023.

[177] <https://www.stmaryscement.com/Documents/Bowmanville%20CRC/2018%20Sept%2011th%20CRC%20Minutes.pdf>.

[178] Scales, M., "St Marys Cement builds lasting legacy," Canadian Mining Journal, April 1, 2017. <https://www.canadianminingjournal.com/featured-article/st-marys-cement-builds-lasting-legacy/> accessed 12 April 2023.

[179] "Shockwaves of Dissent from Quarry Neighbors," *The Connection Newspapers*, December 7, 2006, <http://m.connectionnewspapers.com/news/2006/dec/07/shockwaves-of-dissent-from-quarry-neighbors/> accessed 09 April 2023.

> *"Those who live near the quarry, located on Ox Road just south of the new Fairfax Water treatment plant, have two major complaints they want Vulcan to address: the amount of traffic created by trucks loaded with tons of stone leaving the quarry daily, and the impact the blasting has on their lives, through the noise and tremors caused by the explosions…."*
>
> *"Although the quarry has been in business since the 1950s, the area surrounding it has undergone drastic changes in the past few years since the prison closed, said Mike Grogan, another Southpointe resident. As the population has increased, homes have been built closer to the quarry, and the people who live there weren't prepared for the blasts".*
>
> *"Many of the residents who live near the quarry thought they were the only ones feeling the aftershocks of the blasts in their homes, Grogan said, and didn't report their concerns or complaints to anyone. It was only at the November [2006] meeting of the South County Federation that Supervisor Gerry Hyland (D-Mount Vernon) became aware of the situation, he said."*
>
> *"The Fairfax County requirements demand a 0.4 [inch/sec] [10.16 mm/sec] peak particle velocity [PPV] and a 130 air over pressure [airblast] decibel reading…. Vulcan detonates between 20,000 pounds and 25,000 pounds of explosives twice a week at the quarry….The operating hours for the quarry are 7 a.m. until 6 p.m. during the week…"*[180]
>
> *"While Vulcan has never been found to be operating in excess of Fairfax County requirements, McKernan [Deputy Chief of the Fire Prevention Division] said he believes the blasting industry needs stricter regulations…."*
>
> *"McKeeman said there's a long list of books that state the damages found in these neighboring homes are common and can be found in neighborhoods that are nowhere near quarries."*

2.21 Ongoing Complaints of Damage from Blasting at Rogers Group Quarry (Hendersonville)

Residents as far away as one mile (1,609 metres) have been complaining for years about the damage to their homes, which they attribute to the Rogers Group Inc. blasting quarry operations. By 2018, more than 330 residents joined a Facebook Group (Saundersville Area Blasting Concerns), with the following conversations:

> *Some neighbours in Hendersonville [Tennessee] say far too often the earth is moving beneath them and loud blasting at a nearby quarry is making them lose control of their homes. Now, the city is coming forward with something that might help. There's a crack in a window on Saundersville Road. The homeowner believes it's not because of anything in her neighbourhood, but rather the rock quarry nearby. "I'm hearing from some of the neighbours about the impact on their homes," said*

[180] "Vulcan's Uncertain Future in Lorton, Vulcan Quarry's special-use permit may not be renewed based on neighbor's complaints of structural damage," *The Connection to your community*, April 4, 2007, <http://www.connectionnewspapers.com/news/2007/apr/04/vulcans-uncertain-future-in-lorton/> accessed 09 April 2023.

> *Hendersonville Mayor Jamie Clary. "They're seeing that pictures are being moved, glasses are being rattled. They're worried it's having an impact on their foundations or walls or other parts of their homes." [Mayor] Clary said he lives in the area hit by blasting. Another neighbour told News4, "he feels helpless investing in a house when he has no control over damage to it. He said he would never have built in the neighbourhood if he knew the problem was this bad." A lot of the worries were voiced in the Facebook group, Saundersville Area Blasting Concerns, now* with more than 330 members.[181]
>
> *Wyncrest resident Tasha Buttrey had just moved in three weeks prior when she first felt the ground shake in 2018. She says it wasn't long before she learned from neighbours that a quarry owned by Rogers Group was nearby. "The house shook and knocked a mirror off the wall," she said. "We heard a pop and we watched it crack the dry wall around the door frame." Buttrey says, "she didn't bother filing a formal complaint with the state fire marshal's office who regulates the blasting, or Rogers Group."*
>
> *"Proving the damage is directly due to blasting, is nearly impossible," she said. To make matters worse, when one files a complaint with the fire marshal's office, the state office obtains its readings from Rogers Group itself, Buttrey noted. The readings rarely if ever show the quarry is in violation of state standards.*
>
> *"The community is left with very little recourse," she added. "Everybody feels pretty hopeless about it." For their part, Rogers Group and the third-party company it hires to monitor its blasting, has consistently said it is well within the state guidelines. "We are always way under the state requirements," Rogers Group Area Vice President Bryan Ledford told the Hendersonville Standard in March of 2018. While the state requirements are one to two inches per second peak particle velocity, Rogers Group targets.5 inches [per second or 12.7 mm/sec], he said. "Just to make sure we stay below the legal limits." State Rep. Terri Lynn Weaver (R-Lancaster) says, "she would like to see the state limits lowered to meet federal standards, and has introduced legislation that revises portions of the state's Blasting Standards Act of 1975".*[182]

2.22 Public Complaints of Damage from Blasting as Far Away as Two Miles from the Quarry

Some forty residents within two miles (3.22 kilometres] have filed a litany of complaints against Arkhola Sand and Gravel Co.'s Roberts Quarry, a blasting quarry southwest of Tahlequah, Oklahoma (Palmer, 1985).[183]

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[181] <https://www.wsmv.com/news/neighbors-claim-rock-quarry-blasting-creates-problems-for-nearby-homes/article_cba4c58e-5ae3-51a0-a272-8431dff528c8.html>

[182] <https://www.hendersonvillestandard.com/news/blasting-complaints-about-local-quarry-prompts-bill-to-revise-state/article_f59581dc-5f34-11ea-9a0e-6fc489384d49.html>.

[183] Palmer, G.., "Quarry Blasts Rattle Residents, Stir Up Lawsuit," The Oklahoman, March 17, 1985, <https://www.oklahoman.com/article/2101866/quarry-blasts-rattle-residents-stir-up-lawsuit> accessed 09 April 2023.

> *There was a rapid series of muffled detonations, and 8,000 tons of limestone slowly peeled away for the 40-foot thick formation. Over a ridge, roughly 4,800 feet [1,463 metres] west of the explosion, Elsie Torix noted the blast on her calendar. "I felt everything start to shak[e]," she recounted later that afternoon. "It was just like an earthquake. It was a small one, compared to what they usually put off."*
> *Superintendent Darwin Tackett said Friday's [March 15, 1985] "shot" was typical of a normal working day at Arkhola Sand and Gravel Co.'s Roberts Quarry…*
> *Friday's blast couldn't possibly have damaged Elsie and Louie Torix's mobile home, Arkhola officials said. Neither could any of the other shots that since 1978 have opened up the limestone quarry, Tackett said. But the Torixes and 39 other property owners in around the Zeb community cite a litany of grievances against the quarry. Residents blame the blasting for drying wells, dirtying well water, cracking brick veneer, breaking windows and wrecking mobile homes.*
> *Confronted with claims of structural damage in homes one and two miles from the quarry, Arkhola officials point to their cinder-block control block building at the very edge of the quarry. If the blasting damaged buildings, they say, it would certainly have damaged the control house by now….*
> *1n a 1980 jury trial, the Torixes won a $31,000 judgment against Arkhola. They said Arkhola's blasting ruined their well and destroyed their mobile home. At the 1980 trial, expert witnesses for Arkhola testified that the blasting could not possibly have affected the well and trailer. The Torixes' first trailer sat atop a ridge overlooking the quarry. The Torixes said when the blasting ruined that trailer; they mortgaged a new mobile home and set it up below the ridge, away from the blasting. Still, they claim, the trailer is beginning to show the same structural stresses that eventually destroyed the other trailer. When the Torixes sued Arkhola in 1980, the firm offered to buy them out for $500 an acre. The Torixes spurned the offer. The farm is worth twice that, they said. The Torixes said they took a live-and-let-live attitude when they first learned Arkhola had leased 900 acres from a nearby landowner. But the Torixes' benevolence quickly faded. "The first shot they put off out there, those damned dishes fell out of the cabinet," Louie Torix said….*

2.23 Complaints of Damage Persist Over Quarry Blasting Operations in Victoria, Australia

As reported in the 2017 issue of Quarry Magazine,[184] the number of complaints from communities in proximity to blasting quarries in Victoria, Australia, has been on the rise. As is typical, quarry operators/blasters inevitably respond by denying responsibility for any property damage occasioned by blasting operations.

[184] "Managing safer blasting under community scrutiny," Quarry, May 2, 2017, <https://www.quarrymagazine.com/2017/02/05/managing-safer-blasting-under-community-scrutiny/> accessed 09 April 2023.

> *"Flyrock, lack of blast area security, premature blasts and misfires are the four major areas of injuries and fatalities from blasting in open cut mines and quarries…. More recently, quarries and mines close to houses, along with regulators, have been responding to complaints from the community that blasting is causing damage to their homes. Approvals of residential developments near existing quarries are contributing to the increased number of complaints."*
> *"The common response from our industry, that the ground vibrations and air blast levels measured at their property are within the limits specified in approvals, will not alleviate the concerns of householders that cracks in plaster or brickwork are attributed to blasting."*

3. CONCLUSION

Blasting quarry operations cause untold adverse effects on the environment and its inhabitants. A number of jurisdictions have reached the conclusion that indirect impacts such as *Airblast (Concussion)* and *ground vibrations* stemming from blasting rock with explosives are just as much an invasion of public and private third-party property as if struck directly by flyrock, with all three impacts emanating from the same event (i.e. detonation of explosives to break rock) held to strict liability.

The only effective remedies for reducing or eliminating adverse effects, such as those listed under the *Ontario* Environmental Protection Act (EPA), are mandatory minimum setbacks of 500 metres provided and confined to the lands of the quarry owner, accompanied by minimum separation distances of 1,000 metres between the quarry and incompatible land uses. The permitted PPV of 12.5 mm/second for ground vibrations in Ontario, Canada, is far too high, and should be reduced to 2.0 mm/second, measured along the entire perimeter of the quarry site, not offsite on public or private property, to minimize and protect the environment and its inhabitants from the adverse effects of blasting such as toxic fumes, noise, flyrock, vibrations, subsidence, etc. Based on the research conducted, here are the concluding observations:

- Blasting rock is an ultra-hazardous activity, and has the potential to injure or kill onsite workers and people offsite, as well as non-human life (e.g., pets, livestock, wildlife, etc.).
- Blasting within regulatory limits does not prevent property damage, even at great distances. (The regulatory limit for ground vibrations of Peak Particle Velocity of 12.5 mm/second in Ontario, Canada, is too high.)
- Vibrations and airblast from blasting rock can cause damage at great distances from the blast site.
- Blasting can traumatize people (especially children, the elderly and disabled), including those suffering from Post-traumatic Stress Disorder (PTSD), and pets, livestock and wildlife.
- Commercial and homeowner insurance policies do not cover property damage caused by blasting.

- Citizen complaints and private lawsuits are common occurrences in response to the adverse effects occasioned by blasting rock, as provincial oversight is often ineffective or non-existent.
- Owners whose property is damaged or depreciated by airblast and ground vibrations from blasting operations are forced to initiate time-consuming and costly civil litigation, which often takes years to resolve, with no guarantee of success.
- Blasting that injures or relies on the use of the property of its neighbours, directly or indirectly, with immunity, is effectively an appropriation (de facto taking) of the neighbours' property without compensation.
- Current residents and future generations lose control over what happens once a blasting quarry operation is established, and are forced to endure the adverse and cumulative effects of quarry operations for the rest of their lives, as quarry operations can last for 100 years or more (five generations); in Ontario, a permit or licence to extract aggregate typically has no expiry date.
- Blasting quarry operations depreciate the value of nearby non-residential and residential property, and erode investor and homeowner equity.
- Non-residential and residential properties near blasting quarries are more difficult to sell, and mortgage financing on favourable terms and conditions is not readily available.
- *Blasting Design* reports as required in Ontario pursuant to the ARA are typically misleadingly labeled as *Blast Impact Assessments*, and the mandated scope of work is so superficial as to render them virtually meaningless and incapable of protecting the environment and its inhabitants from the adverse and cumulative effects occasioned by blasting during the entire life of a proposed blasting quarry operation.

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AUTHOR'S DECLARATION AND ESSENTIAL ETHICAL COMPLIANCES

Authors' Contributions (in accordance with ICMJE criteria for authorship)
This article is 100% contributed by the sole author. S/he conceived and designed the research or analysis, collected the data, contributed to data analysis & interpretation, wrote the article, performed critical revision of the article/paper, edited the article, and supervised and administered the field work.

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Research involving human bodies or organs or tissues (Helsinki Declaration)
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals not even indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

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The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

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